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ABSTRACT

The annual report of the Department of Computer and Information Science includes abstracts of research carried out during the 1976-77 academic year with support from grants by governmental agencies and industry, as well as The Ohio State University. The report covers the department's organizational structure, objectives, highlights of department activities, grants, faculty appointments, undergraduate and graduate programs, course offerings, and facilities. Abstracts, indexed by subject and investigator, are given for 65 papers in the areas of information storage and retrieval; information analysis; linguistic analysis; artificial intelligence; information processing in physical, biological, and social systems; mathematical techniques; systems programming; computer architecture and networks; computational theory; and joint programs. Appendices include statistical data on the growth of OSU's Department of Computer and Information Science and lists of courses (by number and title), department faculty, Computer and Information Science Seminar Series presentations, and publications by department staff. (Author/JPF)

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ANNUAL REPORT

and

ABSTRACTS OF RESEARCH

JULY 1976 - JUNE 1977

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

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TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) AND USERS OF THE ERIC SYSTEM."

Department of Computer and Information Science

The Ohio State University

Columbus, Ohio 43210

IR005 759

FOREWORD

This publication contains the annual report of the Department of Computer and Information Science and abstracts of research which has been carried on duing the 1976-77 academic year. This research has been supported in part by grants from governmental agencies and industry, as well as by The Ohio State University. Sponsorship with units other than the Department of Computer and Information Science is identified at the end of an abstract.

The Department of Computer and Information Science is a separate academic unit located administratively in the College of Engineering, operating in part as an interdisciplinary program with the cooperation of many other departments and colleges throughout the University. Under the department is the Computer and Information Science Research Center which is the publishing outlet for a technical report series. Research of the faculty and graduate students in the Department of Computer and Information Science is reported periodically in this series. A bibliography of the research reports published by the Center is included in this publication as Appendix G. Copies of some of these reports are still available on a complimentary basis from the Computer and Information Science Research Center,The Ohio State University, 2036 Neil Avenue Mall, Columbus, Ohio, 43210. Titles with PB or AD numbers may be obtained from The National Technical Information Center, The U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia, 22151, in paper copy, magnetic tape, or microfiche. There is a nominal charge for their service.

Marshall C. Yovits
Chairman, Department of
Computer and Information Science

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I. THE ANNUAL REPORT OF THE DEPARTMENT OF COMPUTER AND INFORMATION SCIENCE

Computer and information science deals with the body of knowledge concerned with the quantitative relationships, concepts, theory and methods common to the processing and utilization of information, and with the theory and operation of the systems which process information. The study of both natural and artificial languages as modes of communication and of natural and artificial systems which process information is fundamental to computer and information science. Common properties of information are induced logically by the study of specific systems and specific areas of science and technology which have a concern with the handling of information. Information is defined as data of value in decision making.

ORGANIZATIONAL STRUCTURE

The Department of Computer and Information Science is a separate academic unit located administratively in the College of Engineering, operating in part as an interdisciplinary program with the cooperation of many other departments and colleges throughout the University. The department was organized in 1966 and achieved departmental status in 1968.

OBJECTIVES OF THE DEPARTMENT

The program at The Ohio State University emphasizes education, research service and the professional practice and application of computer and information science. The educational program offers undergraduate and graduate degrees through the Ph.D. The research activities which are a central part of the program consist of a broad conceptual base supported by a number of contracts and grants as well as by the university. The broad core research program and these other research tasks interact to form an integrated framework.

HIGHLIGHTS OF DEPARTMENT ACTIVITIES, 1976-77

* A Cooperative Work Program for undergraduate majors in Computer and Information Science was initiated between the Department of Computer and Information Science and business and industry.

* A Distinguished Lecture Series brought seven outstanding lecturers to the department:

  Arthur W. Burks, Professor Computer and Communication Sciences and Professor of Philosophy, The University of Michigan

  Edward A. Feigenbaum, Professor and Chairman, Computer Science Department, Stanford University

Edsger W. Dijkstra, Extraordinary Professor of Mathematics, Eidenhoven, University of Technology, The Netherlands;

Paul Armer, On-Line Business Systems, Inc.;

Juris Hartmanis, Professor of Computer Science, Cornell University

Gene Amdahl, Chairman of the Board, Amdahl Corporation;

Seymour Papert, Professor of Mathematics, Cecil and Ida Green Chair Professor, Massachusetts Institute of Technology.

* Enrollment in all programs was 7,615 students

* Degrees awarded were 5 Ph.D. degrees, 70 Masters' degrees, 118 Baccalaureate degrees.

* Grants:

1. Aspects of Decision Theory with Applications to Target Recognition and Digital Communication, U.S. Air Force Office of Scientific Research (AFOSR 72-2351), Principal Investigator: Balakrishnan Chandrasekaran

2. Development of a General Theory of Information Flow and Analysis National Science Foundation, Division of Science Information, (NSF-DSI 74-04766A01), Principal Investigator: Marshall C. Yovits;

3. Development of Information Measures and Their Application to a General Theory of Information Flow and Analysis, National Science Foundation, Division of Science Information, (NSF-DSI76-21949) Principal Investigator: Marshall C. Yovits;

4. Performance Measurement Methodologies for the Design and Analysis Information Systems, National Science Foundation, (NSF-SIS75-21648), Principal Investigator: Lee J. White;

5. A Proposed Classification System to Augment SDI Profiles for the Circ II System, Rome Air Development Center (F30602-76-C-0102) Principal Investigator: Lee J. White;

6. Research on Data Secure Systems, Office of Naval Research, (CNR-N0014-75-C-0573), Principal Investigator: David K. Hsiao;

7. Theoretical Research on the Translation of Phase Structure Languages, U.S. Air Force Office of Scientific Research (AFOSR-75-2811), Principal Invesigator: H. William Buttelmann;

8. The Dow Chemical Fund in Computer and Information Science, Dow Chemical, U.S.A (3527), Principal Investigators: Marshall C. Yovits, Anthony P. Lucido.

* A new graduate program option was added as Option VIII for the student specializing in mathematics.

* Faculty appointments, promotions, leave of absence, and resignations:

Balakrishnan Chandrasekaran was promoted from Associate Professor of Computer and Information Science to Professor of Computer and Information Science.

Thomas G. DeLutis was promoted from Assistant Professor of Comptuer and Information Science to Associate Proessor of Computer and Information Science.

Donald L. Kalmey resigned to join the faculty of Applied Mathematics and Comptuer Science Department, Speed Scientific School, University of Louisville, Louisville, Kentucky.

Harvey S. Koch resigned to join the faculty of the Graduate School of Management, The University of Rochester, Rochester, N.Y.

Anthony P. Lucido resigned to join the faculty of the Computing Sciences Division, Industrial Engineering Department of Texas A&M College Station, Texas.

Howell H.W. Mei accepted the postion of Assistant Professor of Compuer and Information Science.

Bruce Russell resigned to join the faculty of the Department of Computer Science, University College, Cork, Ireland.

Richard R. Underwood accepted the position of Assistant Professor of Computer and Information Science.

* National Recognitions:

Balakrishnan Chandrasekaran was an Honorable Mention winner of the Second Annual Pattern Recognition Society Award for his paper entitled "AHeuristic Strategy for Developing Human Facial Images on a RT" (Co-author: M.L. Gillenson);

David K. Hsiao was appointed to the Governing Board of the IEE Computer Society, December 1976-December 1978;

Jerome Rothstein received the Best Paper Award for his paper entitled "On the Ultimate Limitations of Parallel Processing" presented at the 1976 International Conference on Parallel Processing, Detroit Michigan.

Marshall C. Yovits was elected to the ACM Council, East Central Region

INSTRUCTIONAL PROGRAMS

The program of the Department of Computer and Information Science is broad and extensive. Those instructional areas which are emphasized by the Department of Computer and Information Science are as follows:

1. General theory of information
2. Information storage and retrieval.
3. Theory of automata and theory of computation.
4. Artificial intelligence.
5. Pattern recognition.
6. Computer programming, including system programming.
7. Theory and processing of programming languages.
8. Digital computer architecture and organization
9. Numerical analysis.
10. Man-machine interaction and systems.
11. Formal and computational linguistics.
12. Management information and systems.
13. Biological information processing.
14. Social, economic, and psychological aspects of information production and processing.

The number of students enrolled in all programs was 7,615. A total of 118 students received baccalaureate degrees, 70 students received the M.S. degree, and 5 students received the PH.D. degree. The number of applications for graduate study during this period was 333. Seventy-seven graduate students received support from the department. There was a total of 22 full time faculty and 12 parttime faculty. For additional statistics see Appendix A.

Undergraduate Programs

Undergraduate degrees in computer and information science are available to students in the College of Engineering, the College of Mathematics and Physical Sciences of the College of the Arts and Sciences, and the College of Administrative Sciences. The particular program chosen depends upon the students's interests and career objectives.

The undergraduate program in the College of Engineering leads to the degree of Bachelor of Science in Computer and Information Science. This program is designed for the student who wants to specialize in computer and information science from within an engineering environment. Hence, the program provides the student with a core of computer and information science, mathematics, and engineering science. Both depth and breadth in computer and information science are assured by specific required course sequences in several areas of engineering and science yet, sufficient flexibility exists so that a student can elect a portion of his technical course work in order to develop his individual interests.

There are two undergraduate programs in the College of Mathematics and Physical Sciences. These programs lead either to the degree of Bachelor of Science or the degree of Bachelor of Arts with a major in computer and information science. The programs are cast in a liberal arts setting and are similar in content. The Bachelor of Science program provides a somewhat more technical and thorough education in computer and information science and mathematics while the Bachelor of Arts program is somewhat more flexible and provides an opportunity to relate computer and information science to some other discipline.

The undergraduate program in the College of Administrative Science leads

to the degree of Bachelor of Science in Business Administration with a major in computer and information science. This program is designed for the student that is business oriented and desires an education in computer and informaton science and a general education in the administrative sciences. The program's objective is not to make a computer specialist out of a student, but rather to enable him to recognize the opportunities to use the computer in his managerial activities, to know what to expect from it, and to know how to communicate effectively with computer specialists so that computerized projects will be properly handled from a technical as well as a managerial point of view.

Graduate Programs

The Department of Computer and Information Science offers graduate programs leading to both the Master's and Ph.D. degrees. The graduate program leading to the Master's Degree is available in eight options.

Option I for the student desiring a theoretical foundation in computer and information science.

Option II for the student specializing in information systems.

Option III for the student specializing in computer systems.

Option IV for the student specializing in numerical analysis.

Option V for the student specializing in operations research

Option VI for the student specializing in biomedical information processing.

Option VII for the student specializing in administrative science

Option VIII for the student specializing in mathematics.

Each of these options provides a background in several aspects of computer and information science, as well as additional mathematical sophistication appropriate to the student's interest. Each of the options may lead to the Doctoral program in computer and information science, and each may be taken with a thesis option or without a thesis option. (See Appendix B for a listing of courses by number and title.)

All courses of study at the Master's level require completion of a core program in computer and information science, together with the required courses specified for one of the options and additional courses as specified by the student's adviser. The core program includes courses on: Principles of Man-Machine Interaction, Numerical Analysis, Computer Systems Programming Advanced Computer Program, Digital Computer Organization, Data Structures, Mathematical Foundations of Computer and Information Science, Introduction to Linguistic Analysis, Modern Methods of Information Storage and Retrieval, and Advanced Seminar in Computer and Information Science.

The graduate program leading to the Doctoral Degree in Computer and Information Science is flexible in that it is tailored to the particular

background and interests of the individual student. These interests may lie in any one of the research and instructional areas already listed as well as in many other cognate areas. A cognate field is defined as a field supporting or closely related to the fourteen Departmental fields and is ordinarily specified by an integrated program of study in other departments of the University.

Course Offerings

Currently there are about 81 courses (each one quarter in length) offered by the Department, 22 of which are largely undergraduate with the remainder being upper level undergraduate and graduate courses. In addition to these courses there are over two hundred courses offered by a variety of departments of the University which are of interest to our graduate students who are encouraged to take these courses.

Faculty

The Department of Computer and Information Science has a full time faculty of twenty-one members at the assistant professor level and above. They have a wide range of backgrounds and experience. The above faculty is supplemented by staff who have joint appointments with other departments; by staff from other departments who teach courses primarily for Computer and Information Science students; and by adjunct staff people who are employed in off campus organizations who teach courses in the Department of Computer and Information Science (see Appendix C). There are currently a total of about 13 supplemental staff in this category.

FACILITIES

Computing Facilities

Computing facilities available to students are among the best in the country. The Instruction and Research Computer Center (IRCC) maintains an IBM S370/168 with batch and timesharing terminals throughout the campus. In addition, the IRCC/CIS Computing Laboratory has a DECsystem-10 with batch and timesharing facilities, and a MICRODATA 1620 with a microprogrammable control store, which are used mainly by the Deparment for teaching and research. The hardware connected with the DECsystem-10 includes several CRT character terminals, a graphics CRT terminal, a CALCOMP plotter, and a speech synthesizer.

Mechanized Information Center (MIC)

The University has established a university-centered-information system called the Mechanized Information Center (MIC). MIC operates as a department of the University Libraries and has both batch and online search services. The MIC batch services are unique to the OSU Libraries. There are both retrospective, or one-time, searches which provide a review of the past literature, and current awareness, or updating, services which continually scan the newest literature on a regular schedule. Batch retrospective searches, covering the past three to four years, are available in science, social science, and education. Batch current awareness services, which provide bi-weekly or monthly updates, are available in science, social sciences, education and chemistry.

MIC also offers online retrospective searches through the facilities of three organizations outside OSU: Lockheed Information Systems, Systems Development Corporation and the Energy Research and Development Agency (ERDA). There are more than 70 data bases in all subject areas covering the past two to ten or more years of literature.

Health Sciences Library

The Reference Department of the Health Sciences Library offers online searches of several biomedical data bases. MEDLINE, primarily a computerized version of index Medicus, provides coverage of worldwide medical literature. Related data bases include TOXLINE and CANCERLINE. Both retrospective and updating services are available.

Reference Department, Main Library

The Main Library Reference Department provides online searches of the New York Times INFORMATION BANK. This contains references to articles in the New York Times (back to 1969) as well as other newspapers and periodicals (back to 1972).

The Ohio College Library Center (OCLC)

The Ohio College Library Center was formed by the Ohio College Association in 1967. The Center operates a shared computerized library network connecting academic, public and school libraries in 46 states. This system has over 1700 specially designed CRT terminals in over 900 institutions that participate online. The Ohio State University Libraries participate in this system and faculty of the Department of Computer and Information Science cooperate on research projects with the Center.

INTERACTION WITHIN THE UNIVERSITY

The Department of Computer and Information Science interact with other departments and research programs within the University because of the multidisciplinary nature of the activities encompassed in this field. A number of the academic faculty have joint appointments in other departments. Staff members of the Department of Computer and Information Science have appointments in the following departments and organizatons:

a. Accounting
b. Allied Medicine
c. Art
d. Biophysics
e. Electrical Engineering
f. Engineering Graphics
g. Instruction and Research Computer Center
h. Mathematics
i. Psychology
j. University Libraries
k. University Systems Computer Center

INTERACTION WITHIN THE COMPUTER AND INFORMATION SCIENCE COMMUNITY

Columbus, Ohio is one of the major centers for information science and for the transfer of information in the United States. A number of organizations

are involved with the activities of computer and information science. This affords an opportunity for students and faculty to interact with appropriate personnel in these organizations. Some of these are:

a. Chemical Abstracts Service
b. Battelle Memorial Institute
c. Bell Laboratories
d. City National Bank
e. Columbus and Southern Ohio Electric Company
f. Western Electric Corporation
g. Rockwell International Corp.
h. Industrial Nucleonics
i. State of Ohio Department of Finance; Department of Highways
j. Columbus Board of Education
k. Ohio College Library Center

There are a large number of scientists who come to Columbus in order to visit with the Department and who usually present a seminar. (The lectures and seminars for the period of this report are listed in Appendix D) . These persons cover virtually all phases of computer and information science. This year the Department also sponsored a Distinguished Lecture Series with seven outstanding speakers. Guest lecturers for this series are listed in Table 1.

In addition, our people interact at most of the major technical meetings in this country as participants giving papers, assisting on panels, as attendees, and as officials. Hardly a major technical meeting in the appropriate fields is held without a contribution from one or more of the personnel from the Department of Computer and Information Science (CIS). A list of these activities can be found in Appendix E.

Research efforts of the staff are disseminated to the professional community through several publication channels. A list of current publications of the Department staff is included as Appendix F. In addition, the Research Center issues a technical report series (see Appendix G).

DOCTOR OF PHILOSOPHY DEGREE

The Doctor of Philosophy degree was awarded to the following students during 1976-77. See Appendix H for a complete listing of Ph.D. dissertations.

Name	Dissertation
Tu-Ting Cheng	Design Consideration for Distributed Data Bases in Computer Networks
Ehud Gudes	An Application of Cryptography to Data Base Security
Dov Isaacs	Computer Operating System Facilities for the Automatic Control and Activity Scheduling of Computer-Based Management Systems
Ramachandran Krishnaswamy	Methodology and Generation of Language Translators
Ernest W. Leggett, Jr.	Tools and Techniques for Classifying NP-Hard Problems

Table 1: Distinguished Lecture Series

October 14, 1976, "From Eniac to the Stored Program Computer: Two Revolutions in Computers," by Arthur W. Burks, Professor of Computer and Communication Sciences and Professor of Philosophy, The University of Michigan;

November 18, 1976, "Applications of Artificial Intelligence to Science and Medicine," by Edward A. Feigenbaum, Professor and Chairman, Computer Science Department, Stanford University;

January 13, 1977, "The Formal Derivation of Computer Programs," by Edsger W. Dijkstra, Extraordinary Professor of Mathematics, University of Technology, The Netherlands;

January 27, 1977, "Electronic Funds Transfer Systems," by Paul Armer, On-Line Business Systems, Inc.;

February 17, 1977, "Computational Complexity," by Juris Hartmanis, Professor of Computer Science, Cornell University;

March 10, 1977, "Gazing into the Large System Crystal Ball," by Gene Amdahl, Chairman of the Board, Amdahl Corporation;

April 28, 1977, "Computers and Children," by Seymour Papert, Professor of Mathematics, Cecil and Ida Green Chair Professor, Massachusetts Institute of Technology.

II. INFORMATION STORAGE AND RETRIEVAL

AUTOMATIC SEQUENTIAL DOCUMENT CLASSIFICATION

An automatic classification technique has been applied to a large data base, the Air Force Central Information Reference and Control (CIRC) II System. This system presently consists of over four million documents and deals with diverse technical subject areas in science, engineering, and technology. A set of approximately one hundred classes was developed to appropriately describe the subject content of this data base.

This classification technique assumes the classes to be specified a priori. A sequential approach is utilized in which only a portion of the document is scanned before one or more classes are assigned which best describe the subject content of the document. The sequential approach can be applied in a situation where a tradeoff is required between classification accuracy and processing time. Classification accuracies of over 80% assigned classes correct and 90% of the documents assigned at least one correct class have been achieved, while processing over twenty documents per second.

Documents which change subject areas several times pose an interesting problem for classification. An investigation of documents has shown that these changes in subject can be detected and the document appropriately classified.

L. J. White, A. E. Petrarca, L. Crawford, B. Brinkman, S. Mittal (Sponsor: Ronce Air Development Center. Contract F30602-76-C-0102)

A BIBLIOMETRIC ANALYSIS OF CLOTHING LITERATURE WITH IMPLICATIONS FOR INFORMATION STORAGE AND RETRIEVAL

Because of the dispersion of the clothing literature among a variety of primary and secondary publications, researchers in the field of clothing have long been concerned with problems of gaining access to the literature relevant to their interests. Consequently, a bibliometric analysis of the clothing literature was undertaken to determine the feasibility and constraints of using two well-known bibliometric techniques (i.e., bibliometric coupling and Bradford analysis) to (1) create a comprehensive bibliography for a small interdisciplinary field such as clothing and (2) to identify the core publications which are responsible for producing a significant part of the scholarly literature of such a field. The results of the study not only established the practicality of using these techniques for such a purpose but also provided data to test some new hypotheses regarding bibliographic coupling relationships.

A. E. Petrarca, N. I. Fetterman, L. E. Dickey

FUNCTIONS FOR EVALUATING THE EFFECTIVENESS OF AUTOMATIC VOCABULARY CONTROL TECHNIQUES USED ON KEYWORD INDEXES DERIVED FROM NATURAL LANGUAGE TEXT

Vocabulary control is introduced into printed keyword indexes derived from natural language text to reduce the amount of concept scattering which would otherwise result from the many inflectional and derivational forms of words used to represent the various concepts. To evaluate the effectiveness of some automatic vocabulary control techniques being studied, several approaches to the development of an objective and quantitative method for evaluating such techniques have been explored. Most of them are intuitively based on the difference in index entropy between any given index and its corresponding ideal index (i.e., one which is free of concept scattering and ambiguity) as a means of quantifying the extent to which a particular vocabulary control technique improves the qualities of an uncontrolled index. One approach utilizes a function based on an adaptation of the relationships embodied in Shannon's communication theory. This approach is basically concerned with how well the concepts are represented (transmitted) by the keywords or index terms of any given index, and how well the index terms convey the desired meanings. A second approach utilizes a function based on how the various index vocabulary problems (scattering, ambiguity, etc.) affect the index user. In either of the above approaches, as well as in others that have been considered, the functions provide a single numerical value which can be used as a figure of merit for evaluating the effectiveness of different automatic vocabulary techniques applied to a particular uncontrolled index for which a corresponding ideal index has been constructed.

A. E. Petrarca, W. S. Stalcup

HYBRID METHODS FOR DYNAMIC STORAGE ALLOCATION

The traditional dynamic allocation methods of best fit and first fit have been well studied, and it is known that there are conditions which cause one method to outperform the other, and vice-versa.

An attempt is being made to study an intermediate method which will hopefully combine some of the advantages of both. This method, called "first n fit", selects the first n available blocks which satisfy a request, and then selects the best fit from among this set. For $n=1$ this method reduces to first fit, and it approaches the best fit method as n increases. Preliminary studies have shown that, for $n=2$, the increased search time over first fit is small and that there may be a reduction over first fit in the number of failures encountered.

S. H. Zweben, K. V. Klingeman

INTERACTIVE QUERY-FORMULATION AIDS TO IMPROVE SUBJECT-SEARCH PERFORMANCE IN LARGE DYNAMIC DOCUMENT RETRIEVAL SYSTEMS

It is often a difficult task, even for a knowledgable expert, to think of the most appropriate way of specifying a topic one wants to search in a document retrieval system. A set of interactive aids to facilitate this aspect

of query formulation is being developed to improve the overall performance of searching both dynamic current awareness and large retrospective files. The first aid involves the use of association measures derived from SDI (Selective Dissemination of Information) profiles to determine whether a question identical to, or similar to, the one being formulated by the current user is already on file. Such an aid will allow users to take advantage of the intellectual effort previously expended on development of profiles suitable for their own purposes as well, thereby obviating the need to expend similar intellectual effort over and over again. The second set of aids involves the use of term-term association measures derived from the above profile-term matrix as well as from the document-term matrix for a representative sample of documents taken from a large retrospective file. This set of aids will provide users with synonyms and/or related terms that may be used together with or in place of those initially provided by the user. A third aid involves an interactive relevance feedback capability whereby the user simply indicates whether or not each document retrieved by his profile and displayed on his terminal is relevant to his interests. The system will automatically refine the profile based on this information, following which the user can test and refine the profile again by repeating the process as often as necessary. Appropriate tests to evaluate the effectiveness of these aids towards improving subject search performance in a large dynamic document retrieval system will be conducted.

A. E. Petrarca, B. J. Brinkman

A METHODOLOGY FOR THE PERFORMANCE EVALUATION OF DATA BASE SYSTEMS

A methodology for the performance evaluation of data base systems (DBS) has been developed. This methodology is specifically designed for investigating data base system behavior with respect to application processing requirements, schema and subschema formulations, data base software, and data base content. Attention is focused on the appropriateness of schema and subschema structures with respect to the data base contents and to various system loadings. The first objective of the research was to obtain a functional description of DBS behavior. A DBS is viewed as a subset of a generalized multi-level information processing system. The methodology provides facilities for the characterization of logical data structures in integrated data base environments as well as the characterization of data access activities. The second objective was the identification of a set of criteria for performance analysis. The identified performance measures were chosen so as to be obtainable by the DBA. The specification of a set of algorithms which relate the definitional parameters to the performance criteria was the third objective.

In addition, a realization of the methodology was formulated. This realization was designed as an extension to the capabilities provided by the Information Processing System Simulator (IPSS), a special purpose discrete event digital simulator. This realization consists of the specification of language constructs for defining data base systems. The simulator transforms the declarative and procedural characterizations into outputs which relate to the behavior of the model.

T. G. DeLutis, J. D. Brownsmith (Sponsor: National Science Foundation Grant SIS75-21648)

MODELING OF A LARGE ON-LINE INFORMATION SYSTEM

The objective of this research is to investigate problems related to the simulation of large information systems and to identify the features of a special purpose simulation language (the Information Processing System Simulator, IPSS) which facilitated the modeling function. The modeled system is the Ohio College Library Center (OCLC) system which is a large on-line information system serving over eight hundred libraries throughout the United States and Canada. The central computer facility consists of a multi-processor configuration of four Xerox Sigma-9 computers and an on-line data base of over 2.5 million bibliographic entries. To date, the hardware, data base and input message scheduling components have been modeled. The modular structure of the IPSS model allows validation and verification to be performed on these components. Some problems related to simulation of large information have been identified. Current effort is directed towards modeling the message processing algorithms. Once this is accomplished, validation, verification and experimentation will be done on the overall model.

T. G. DeLutis, J. E. Rush and P. M. K. Wong.

A MULTI-STAGE MULTI-CRITERION APPROACH TO INFORMATION SYSTEM DESIGN

A multi-stage multi-criterion methodology was developed for the purpose of aiding in the design of information systems. As information systems continue to grow in size and complexity, these systems must be designed to satisfy, simultaneously, system performance criteria and user service achievement criteria. This multi-criterion design dilemma was approached in this research through a multi-stage evaluative methodology. Three stages were identified: Stage 1 -- a System Evaluation Stage where the behavior of the information system being designed is modeled and measured; Stage 2 -- a User Goal Evaluation Stage where the performance of the system measured in Stage 1 is evaluated with respect to user oriented goals; and Stage 3 -- a Design Evaluation Stage where the design is evaluated against all criteria and design modifications if necessary, are made. The focus of this research was on the development of Stage 2 including the formulation of multiple goal programming (MGP) based procedures to evaluate the information system with respect to multiple criteria, the establishment of a formal statistical liaison with Stage 2, and the interpretation of the Stage 2 outputs with respect to their use in Stage 3. To demonstrate the practicality of this research, the developed methodology was realized: system behavior was measured via the Information Processing System Simulator (IPSS), the user goal evaluation was made by MGP based procedures and the design was evaluated and redesigned through heuristic procedures. This realization was used to validate the underlying methodology through a series of experiments where design alternative selections using Stage 1 analysis were tested. The result was consistently better performance than random selections. Although this research was directed to analysis of information systems, it is also applicable to a broad range of systems, within and without the realm of information systems, and with or without the particular techniques currently employed in Stages 1 and 3.

T. G. DeLutis, J. S. Chandler (Sponsor: National Science Foundation, Grant SIS75-21648

ON-LINE PERSONALIZED BIBLIOGRAPHIC INFORMATION RETRIEVAL SYSTEMS WITH COMPUTER-READABLE INPUT FROM A CENTRALIZED SEARCH SERVICE.

A prototype on-line personalized bibliographic information retrieval system with computer-readable input from a large centralized search service was implemented on a minicomputer for a small target research group. Such a system will aid the researchers in the management and use of their personalized files which ordinarily are stored on 3 x 5 cards provided by the centralized service from which the bibliographic data is retrieved. In addition, statistics obtained from usage of the personalized computer system will provide an objective method of evaluating the performance of the centralized search service. The prototype system was implemented on a NOVA 800 minicomputer manufactured by Data General Corporation. Further research is contemplated on improved methods of interfacing such personalized systems with the centralized systems from which they are derived, and on the use of such systems for performance evaluation and improvement of the centralized systems.

A. E. Petrarca, J. J. Henry, J. H. Hsu

VOCABULARY CONTROL IN AUTOMATIC KEYWORD-INDEXING SYSTEMS

Typical automatic indexing techniques, such as KWIC and KWOC, are beset by scattering of information among the many inflectional and derivational word-forms describing each topic. The usual approach to the resolution of this problem involves the use of a manually constructed dictionary or thesaurus for determining the preferred (or controlled) index term to be substituted for each uncontrolled word found in the natural language text. The approach taken in this research, however, involves the development of stemming recoding algorithms to create the preferred index terms from the uncontrolled terms on an ad hoc basis. The stemming operations aid in the recognition of conceptually related keywords by removal of their inflectional and derivational endings, while the recoding operations create preferred index terms by appending suitable suffixes to each word root obtained from the stemming operations. The stemming algorithm developed in this research is based in part on rules from previously reported stemming algorithms as well as on some indigenous rules developed with the aid of forward and reverse lexicons prepared from a 10^6 token sample (7×10^4 type sample) derived from the natural language titles of 10^5 journal articles. The recoding algorithm constructs the preferred index term for each concept by appending one of the suffixes removed from the set of words containing the word root for that concept. This approach precludes the possibility of generating control words which are not yet part of the natural language vocabulary. The effectiveness of various stemming algorithms for vocabulary control is being evaluated by an objective and quantitative technique for this purpose (see separate abstract).

A. E. Petrarca, W. S. Stalcup

III. INFORMATION ANALYSIS

APPLICATION OF MARKOVIAN AND BAYESIAN TECHNIQUES TO THE ANALYSIS OF INFORMATION

Information in a management information system is being analyzed by measuring the effect of information on the responses of a decision maker. A methodology is proposed for analyzing decision making which utilizes Markov models and Bayesian probabilities. The Markov model views the processing of information as a sequence of probabilistic events, each event representing a particular state of the decision maker with respect to a system state. Decision state transition probabilities, dependent on the immediately preceding state, indicate a level of information processing. Utilizing the state definition of the Markov model, the application of Bayesian probability analysis results in a measure of the rate in which the particular level of information processing was attained by the decision maker. This methodology has been applied in a study to measure the effect of different information displays in a management decision system. Results of this analysis have indicated some implications to information acquisition, processing, and utilization as well as to information systems design.

R. L. Ernst, M. J. Lee

THE DEVELOPMENT AND APPLICATION OF A THEORY OF INFORMATION FLOW AND ANALYSIS

The objectives of this National Science Foundation-sponsored research program include the following: (1) to develop a theory of information flow and analysis; (2) to identify important parameters and variables in the information process which can be quantified and measured; (3) to develop relationships among the variables which describe their behavior and limitations; (4) to apply this theory to specific practical situations, particularly those involving science information; and (5) to develop both simulation and experimental models for quantification and validation of the theory.

A generalized framework for developing analytical and conceptual relationships involving the flow of information has been suggested. Our formulation depends on the definition that information is data of value in decision-making. A decision matrix together with a value matrix are used to completely define the entire decision situation. These two matrices explicitly relate courses of action to observable outcomes, values of these outcomes to the decision-maker (DM), and the states of nature.

We define the impact that information has on reducing the uncertainty of the decision state as our measure of information. The uncertainty which exists for any decision state is defined as a function of the mean square variance σ of the probabilities of executing the various courses of action. The amount of information in a data set or message can be measured by computing the difference in the amount of information in the decision state after and before receipt of the data. This explicitly relates information to the removal of uncertainty in the decision-maker's mind about which alternative should be

chosen.

We are further interested in the value of information to the decision-maker; we define this in terms of how information affects performance. Performance is measured as average predicted performance, and is defined by a term we call decision-maker effectiveness. Using this term, we define the value of information in a data set to be the resultant change in decision-maker effectiveness. These two basic measures of information (amount and value) provide a basis upon which we can construct a theory of information at the effectiveness level.

In order to examine the validity and utility of our information measures, a general decision-making situation has been simulated. This simulation has enabled us to begin to study the relationship between information, learning, confidence, and the effectiveness of different decision-makers. A learning rule has been developed for the updating of the executional probabilities in the decision matrix after each trial. Modeling the actual decision situation also requires some sort of selection rule which the DM can invoke to determine his probabilities of selecting the various courses of action. Our only assumption, to allow almost full flexibility, is that the DM bases his probabilities somehow on the expected values of the alternatives.

These information measures and related learning and selection rules provide the capability of simulating the flow of information fully, including exogenous and feedback data. Further measures are derived which include decision-maker average performance and decision-maker expected performance. With this framework, we believe that we can accurately describe the use of information in an effectiveness sense and the role of information in the total decision process.

Continuing research involves establishing relationships among these quantities and the significance of each to the information flow process. We are seeking generalized information relationships in an effort to establish fundamental guidelines for information flow, analysis, storage, and processing. In addition, we feel that generalized rules for making decisions under various conditions - a decision calculus - will emerge from this model as well. We are planning to apply this theoretical development to practical situations and indicate how the quantities can be defined, measured, and used in a practical way. In particular, we are developing examples using a bibliographical retrieval system, a production control situation, and a general economic model.

M.C. Yovits, L.L. Rose, J.G. Abilock (Sponsor: National Science Foundation GN 41628 and DSI 76-21949)

IV. LINGUISTIC ANALYSIS

AUTOMATIC GENERATION OF SYNTAX-CONTROLLED TRANSLATORS

We give an algorithm which, given two context free phrase structure language definitions, $\mathcal{D}_1$ and $\mathcal{D}_2$, will produce a program which performs a syntax-controlled transiation from $L(\mathcal{D}_1)$ to $L(\mathcal{D}_2)$ if and only if such a translation defined by $\mathcal{D}_1$ and $\mathcal{D}_2$ exists. We prove that, even for many trivial cases, the problem of constructing such a program is provably intractable. Research is continuing to 1) identify just how complex this problem is, 2) identify significant classes of languages for which the problem is tractable, and 3) develop heuristics to aid in solving the general problem.

H. W. Buttelmann, D. Perry (Sponsor: United States Air Force Office of Scientific Research. Grant 75-2811)

DEVELOPMENT OF A METHODOLOGY FOR NATURAL-LANGUAGE MACHINE-CONTROL ELICITATION EXPERIMENTS

The objective of this work is the development of materials and procedures to assist in the determination of the commands that humans prefer to use in the real-time control of machines. Current efforts center on the design of a tool for the simulation of a machine-control environment. We will essentially engage two CRT's in communication. We currently are considering applying our work to the design of command languages for text-editing systems with special emphasis on large, powerful systems. Within our simulation environment the experimental subject will think he is using a text-editor, when in fact, he will be communicating with another human. The user will be under the impression that the text-editor is completely flexible. Therefore, the set of commands he gives should be indicative of the structure that a human-factored test editing language should have.

N.K. Sondheimer, J. Webb

A FORMAL THEORY OF THE SYNTAX AND SEMANTICS OF PHRASE-STRUCTURE LANGUAGES

A formal definition for a context sensitive semantics for arbitrary phrase structure grammars, called a phrase structure semantics, has been developed. It is a model of the following semantic philosophy: (1) it is phrases which have meaning, and (2) the meaning of a phrase is a function of its syntactic structure, the meanings of its constituents, and its semantic context. A pair (G,S) where G is a phrase structure grammar and S is a phrase structure semantics, is called a phrase-structure language description. The language of a psld is the set of all pairs (w,m) such that w is a sentence of the grammar and

m is a (non-empty) meaning assigned to w by the language definition.

We prove the following results: the sets of sentences and the sets of meanings of phrase-structure languages are just the r.e. sets. Every phrase-structure language has a description using a regular grammar and a context free semantics. For every description D with an unrestricted grammar and context sensitive semantics there is a description D' using a context free grammar and context free semantics such that $L(D) = L(D')$. Furthermore, D and D' are "strongly equivalent" in the sense that the phrase trees assigned by D' to each sentence are just the skeleton trees of the phrase structures assigned by D to the sentence. The notions of "weak" and "strong equivalence" are extended to semantics (if two descriptions are strongly equivalent in a semantic sense, then the structure of their semantic functions is identical -- in a programming sense, the same programs can be used to compute the meanings of the same sentences). In this sense, D and D' are not strongly equivalent. However, if D has a context free semantics, then D and D' are semantically strongly equivalent.

H. W. Buttelmann (Sponsor: Air Force Office of Scientific Research. Grant 75-2811)

PROGRAMMING EFFORT AS INFLUENCED BY LANGUAGE FEATURES AND PROGRAMMING METHODOLOGIES

Recent investigations into the static structure of algorithms has provided evidence which suggests that the mental effort expended by a programmer in writing a program may be estimated by utilizing quantitative measures of the final code. Research is being conducted into the effect of various language features and programming methodologies on these software science measures used in estimating programming effort. Initial results have been obtained in an analysis of the effect of the reduction of common subexpressions on program volume. An expression involving the token-type ratio, the number of types, and the common subexpression length has been derived which predicts how many common subexpression repetitions are necessary before their replacement will result in volume reduction. This line of research is continuing with studies of the effects of different control structures and the effects of structured vs. unstructured programming on the relevant measures. The continued goal of this work is to aid in the development of languages and methodologies which will allow programming to be an easier and more reliable art.

S.H. Zweben, A. L. Baker

SEMANTIC PROCESSING STUDIES FOR NATURAL-LANGUAGE UNDERSTANDING SYSTEMS

We are investigating methods of performing semantic interpretation in natural-language understanding systems. The question under investigation is whether syntactic and semantic processing can be merged. We previously developed a semantic processor, SPS, that depended on syntactic preprocessing. In working on this system, we noted numerous similarities between semantic and syntactic processing. Two alternative attempts at merger are being pursued.

First, SPS is being further developed in order to clarify exactly what syntactic processing is necessary for its operation. Current efforts center on justification of this approach by direct comparison with those approaches that claim to ignore syntax altogether. Secondly, the Augmented Transition Network (ATN) model for syntactic processing is being extended to incorporate as many semantic processing features as possible. This has lead to a language processing unit for the Natural Language Graphics project here at Ohio State University. Current efforts center on integration of methods for processing deviant sentences within the standard ATN grammar.

N. K. Sondheimer, S. Kwasny

SEMANTICS OF DISCRETE COMPUTER SIMULATION MODELS AND ANALYSIS OF STABILITY

The semantics of a discrete computer simulation model can be taken to be an initial value problem of an ordinary differential equation. Once the connection between the formal syntactic object on the one hand, and the mathematical object on the other hand has been realized, properties of one object can often suggest properties of the other. In particular the robustness of a simulation model, how stable it is as parameters vary, can be studied by studying the stability of the differential equation, a topic that possesses a vast amount of literature.

A connection can also be made to difference equations. Finally, an interesting new program semantics tool is used: the restriction of the syntax of a program in order to make the behavior of the program tractable.

D. Moore

TRANSLATION OF ARBITRARY PHRASE STRUCTURE LANGUAGES

We define translation on phrase structure languages and consider a particularly appealing strategy for translation, which we call "syntax-controlled" translation. (We have avoided the term "syntax-directed" because it has had differing uses in the literature.) We prove the following results: Every computable translation is definable as a syntax-controlled translation. For two arbitrary descriptions D and D', it is undecidable whether any syntax-controlled translation from $L(D)$ to $L(D')$ exists. We give an algorithm which, given two arbitrary descriptions D and D', will halt and produce the definition (program) of a syntax-controlled translation from $L(D)$ to $L(D')$ if and only if such a translation definable by D and D' exists.

Syntax-controlled translation requires no semantic computation at translate time (for which one pays a dear price in the time required to generate syntax-controlled translators). To produce the smallest set of target sentences such that each target sentence has at least one meaning in common with the source and such that all translatable meanings of the source are represented, translation time is bounded above by

$$\Pi + (k_1^{k_2 n})\ (k_2 n)!\}\phi,$$

where Π is parsing time, ϕ is the time to check syntactically valid sentences for semantic invalidity, n is input sentence length, and k_1 and k_2 are constants. For a syntax-controlled translation which produces a single target sentence having a meaning in common with the source sentence, translation time is bounded by

$$\Pi + \phi kn,$$

and if there is no semantic deviance,

$$\Pi + kn.$$

H. W. Buttelmann, R. Krishnaswamy, (Sponsor: Air Force Office of Scientific Research. Grant 75-2811)

V. ARTIFICIAL INTELLIGENCE

CLOSENESS AND REFORMULATION: TWO COGNITIVELY-BASED IDEAS FOR PROBLEM-SOLVING

The approach to problem-solving that we are investigating has two components: closeness and reformulation. The closeness measure is a cognitively-based heuristic function, and reformulation provides the problem-solver with new ways of looking at the goal and is mediated by the closeness measure. We have applied the proposed ideas to many problems that have traditionally been used to test problem-solving ideas.

This research is based on the view that at the very base of any problem-solving activity there is a cognitive component. The various problem-solving modes such as search, planning and problem-reduction are not independent, disjointed activities, but work in a coherent way, mediated by input from cognition. A task of any problem-solving theory is to uncover this cognitive role, which tends to be hidden under the accumulation of a number of high-level heuristics.

B. Chandrasekaran, F. Gomez (Sponsor: Air Force Office of Scientific Research. Grant72-2351)

FINITE MEMORY DECISION THEORY

In this research we continue our investigation of the effect of finite memory constraints on some problems in decision theory. The approach is to restrict the memory, measured in bits, for storing the statistic on which the decisions are based. Equivalently, the decision maker may be viewed as a finite-state automaton. Such a viewpoint is important to computer scientists because ultimately the statistical schemes must be implemented by digital computers. The results are also of interest to engineers faced with the problems of designing electrical signal detectors and adaptive controllers. The design of optimal finite memory rules has been explored for the following problems: multiple hypothesis testing, compound hypothesis testing, and the two-armed bandit problem.

The problem of finding a tight lower bound for $P(e)$, the probability of error, for an m-state automaton while testing K hypotheses for $K > 2$ has remained open while the case $K = 2$ has been solved. It is shown that this is a result of the multiplicity of constraints in realizable automata and the difficulty in determining and then incorporating them all in a set of inequalities satisfied by the error probabilities. Yet nontrivial lower bounds can be constructed on the basis of which close-to-optimal automata can be constructed for symmetric problems, and problems on Bernoulli observation space. For example, a sub-optimal scheme is exhibited for the Bernoulli 3-hypothesis testing that requires at most one extra bit of memory, independent of problem

parameters, to match the performance of the optimal m-state automaton. In this sense, this automaton is close to optimal.

The compound hypothesis problem for the case of Bernoulli random variables is solved. Several compound hypothesis testing problems involving the biases of two coins are also solved. A non-Bayesian formulation is adopted to avoid arbitrary assumptions on prior probability distributions. In all cases the automata demonstrated are not just minimax but also possess some additional optimality properties. Optimal automata require randomization. Deterministic automata that are close to optimal within two bits of memory are demonstrated.

The above results on compound hypothesis testing are also applied to the two-armed bandit problem where, given two coins with unknown biases, the objective is to conduct an infinite sequence of tosses so as to maximize the proportion of heads. It is shown that providing the exact information on the bias of one of the coins can save at most one bit of memory. Optimal randomized schemes and a close to optimal deterministic scheme are exhibited.

B. Chandrasekaran, K. B. Lakshmanan (Sponsor: Air Force Office of Scientific Research. Grant 72-2351)

FORMAL THEORIES OF DATA OBJECTS

In the formal verification of programs it is usually necessary to reason about the data object of the program, and the primitive functions and predicates defined over these objects. In particular a proof of program correctness often involves an assertion of the form $P \Rightarrow Q$, where P and Q are assertions about the data. It is essential to have a formal theory of data so that such proofs can be properly dealt with.

When a formal theory is proposed, several questions arise concerning the consistency and completeness of the theory and the relations between the various models for the theory. This research deals with a formal, first order, many sorted theory of linear lists and addresses these questions in detail.

D. Moore, B. Russell

GENERALIZED ORTHOGONAL REGRESSION IN PATTERN RECOGNITION

A paper with the above title, which includes the work reported last year and some extensions of it, has been accepted on the program of the International Conference on Systems Science and Cybernetics, Washington D. C., September 19-21, 1977. The text has been sent off and will appear in the conference proceedings. The basic idea of the paper is first, that statistical pattern recognition should not use standard regression procedures uncritically (e.g. y-on-x regression for least squares straight line data fit or pattern recognition) because they ignore specific knowledge of the pattern itself, and often make arbitrary indefensible choices (e.g. x-on-y regression gives a different line than y-on-x and is no less legitimate), and second, that the proper kind

of regression is orthogonal to the kind of curve to be fitted or "recognized". The paper establishes a basis for a new general theory. Several promising new directions for further research have also been uncovered including (a) connections with problems in the calculus of variations, (b) relations to Wiener statistical filter theory, (c) a suspected tie-in with the study of time series, via ergodic theory, where the ensemble average (in configuration space) is the maximum entropy (or maximum likelihood) estimate of the "cleaned up" pattern, while the corresponding time series "message" represents the action of the pattern-generating semigroup of operators.

J. Rothstein

GRAMMATICAL INFERENCE PROBLEM

The problem of grammatical inference for regular grammars can be solved algorithmically and has application in syntactic methods for pattern recognition and in programming language design. Given a set of strings, S, from the target language L, the algorithm first constructs a minimal grammar M_0 to generate exactly S. In searching for a grammar for L, the algorithm effectively prunes a lattice consisting of all grammars produced by merging nonterminals of M_0. Two such grammars from the lattice are considered in order to find a string x which is generated by exactly one of the two. The lattice is partitioned into two parts, those grammars which generate x and those which do not. Using an oracle, or teacher, to determine whether $x \in L$, the algorithm then eliminates the one part of the binary partition containing grammars which can no longer be considered as candidates for L. This process at each step does maximal pruning of the lattice using the information from the oracle.

The solution has been extended to inference of context-free grammars. This problem cannot be solved algorithmically only due to the unsolvability of the equivalence problem for context-free grammars. A solution is produced in the limit to circumvent this problem.

It has been further shown that the grammatical inference problem is P-Space-hard, and even for one letter alphabets, is NP-hard. Yet the problem is known to be bounded by 2^{n^2}, where n is the number of states of M_0. Work is continuing to further delineate the complexity of this problem and to devise optimal algorithms.

L. J. White, D. A. Marik (Sponsor: Air Force Office of Scientific Research Grant 72-2351)

KNOWLEDGE-BASED VISUAL IMAGE UNDERSTANDING

Work in computer vision has largely revolved around the use of micro-worlds to reduce the complexity of the vision problem. This approach has the disadvantage of encouraging specialized techniques for image understanding

which are not applicable to other domains. A developmental approach to computer vision is proposed which enables the investigation of issues common to all vision tasks. Initial restriction of the image instead of the world has inspired the design of a domain-independent representation and control structure for knowledge-based visual image understanding. In the proposed vision system, an image is first abstracted and represented by a symbolic description composed of visual primitives. The next level of representation is built of modular chunks of primitive knowledge representing visual cues which associate configurations of visual primitives with possible interpretations. Knowledge manipulation units (or experts) are then used to interpret the visual cues. Finally, a control structure is being developed to mediate communication between the knowledge units and to effectively separate the representation of primitive knowledge from its use. An implementation of the proposed visual image understander is planned and extensions to the current design are outlined, providing a basis for future vision systems capable of understanding more complex images as the image restrictions are gradually relaxed.

B. Chandrasekaran, B. Flinchbaugh, S. Mittal (Sponsor: Air Force Office of Scientific Research. Grant 72-2351)

LANGUAGE DESIGN FOR KNOWLEDGE-ENGINEERING

This research is focusing on some fundamental issues in knowledge-based programming, within the framework of an image understanding system. A language is being developed to provide a two level representation for knowledge. One level for representing small modular chunks of largely problem-independent knowledge, and a second level for task-related knowledge organized into 'experts'. It is our philosophy that general knowledge about a domain in the form of facts, associations and heuristics should be represented in such a way that it can be used for different purposes like learning, problem-solving and question-answering. Thus our focus will be on a representation which can be delinked from specific uses of the knowledge. An important issues is, of course, deciding what knowledge belongs where.

A major effort is being made to design flexible control structures, both for data-driven and goal-directed control, so that experts can be written to use the domain knowledge in building intelligent systems. Mechanisms will be provided for communication between experts, based on some characterization of their expertise rather than on the identity of the experts themselves. A related issue is the design of a common data store, which will be used for problem description, intermediate hypotheses and possibly communication between experts.

B. Chandrasekaran, S. Mittal, B. Flinchbaugh, B. Russell (Sponsor: Air Force Office of Scientific Research. (Grant 72-2351)

NATURAL LANGUAGE GRAPHICS SYSTEMS

This research concentrates on the feasibility of constructing a practical graphics system for use by untrained users. A pilot system has been designed

and built to investigate graphical, linguistic, and organizational issues. The system, which is restricted to the domain of lines, points, and circles, allows textual and touch input, and textual and graphical output.

We believe that successful interaction with a system is dependent on the "naturalness" of the modes of communication, both to and from the system. The first phase of our research concentrates on Natural Language input and Graphical output. This will be extended to include I/O in both modes. Such interaction is feasible only if the system has a large amount of knowledge, both about language and pictures, and about the relationship between them. Our investigations center around designing an appropriate subset of English, constructing an analyzer for that subset, determining the knowledge which is required by the system, and structuring that knowledge in a way compatible with its linguistic and graphic components.

A goal of the project is to allow graphical information to be used in the interpretation of linguistic forms and semantic information to be used in the interpretation of graphical structures. In addition, the stored knowledge should be able to support the formation of either graphical or linguistic output in response to commands or questions. Achieving these goals should facilitate man-machine interaction.

As part of the project, current programs and structures in areas of Computational Semantics, Computer Graphics, and Knowledge Representation are being considered with the intention of isolating suitable structures and techniques or identifying the need for new ones. Analysis of hypothetical man-machine dialogues, and our experiences with the pilot system, have led to a better understanding of the degree of interaction between forms of knowledge, and of the possible organization of the knowledge. Suitable domains for use in the development of future systems are also being considered.

It is not the major purpose of this research to develop totally new methods in Artificial Intelligence, Natural Language Processing, or Computer Graphics, but instead to integrate previously unmarried techniques in those areas. However, several unsolved problems have already been uncovered which has added impetus to the research.

B. Chandrasekaran, D. C. Brown, H. W. Buttelmann, S. C. Kwasny, A. P. Lucido, N. K. Sondheimer

THE REPRESENTATION OF KNOWLEDGE FOR A NATURAL LANGUAGE GRAPHICS SYSTEM

This research is concerned with the design of a Knowledge Base component for a computer graphics system with both linguistic and graphical input and output. It concentrates on techniques for representing graphical, linguistic, and other forms of knowledge in a manner which will allow any combination of these to be used in the process of generating an output from the system. The work is directed towards the representation of objects rather than of events or actions.

The process of selecting appropriate information from the knowledge and

processing it into either graphical or linguistic output is being investigated. This involves finding suitable representations for the various stages of processing -- from conceptual to pictorial for example. General descriptions of classes of objects are used, with additional information from the user, to form representations of particular objects. These are then mapped into a form usable by a computer graphics system.

B. Chandrasekaran, D. C. Brown (Sponsor: French Fellowship)

SPACE-TIME ZONES: REPRESENTING THE MEANING OF SPATIAL AND TEMPORAL REFERENCE

Being considered is the representation of the semantic structure of spatial and temporal references in English sentences. Both the predicate calculus and semantic nets are being used as representational formalisms. That temporal reference is made of only events and states of affairs is well accepted. We have previously shown that the same can be said of spatial reference. Now being developed is a merger of these representation methods in a uniform representation called "space-time zones". These structures will show the location of events and states of affairs in space and time together. Most spatial and temporal references will make reference to the separate components. But such references as motional and directional spatial references will consider the two aspects concurrently.

N. K. Sondheimer

STRAIGHT LINE PATTERN RECOGNITION WITH CELLULAR AUTOMATA

Work initiated last year has progressed satisfactorily and is expected to be incorporated into a dissertation "Parallel Processing and Statistical Pattern Recognition on Bus Automata". The current status is essentially as follows . With the cells of the automaton taken as squares of a Cartesian plane (coordinate "paper") and data points presented as signals to the cells on whose squares they fall, we fit the statistically "best" straight line by orthogonal regression. Parallel routines have been devised which perform all the required computations immediately in practically all cases. These include statistical as well as arithmetical calculations.

J. Rothstein, J. Mellby

VI. INFORMATION PROCESSES IN PHYSICAL, BIOLOGICAL AND SOCIAL SYSTEMS

AN ANALOG/DIGITAL INTERFACE ALLOWING ON-LINE ACQUISITION AND ANALYSIS OF PHYSIOLOGICAL DATA

An Analog/Digital Computer System was designed to allow direct, on-line analysis of several parameters associated with Respiratory Physiology. Analog computation is performed at the experimental site using calibrated transducer signals indicating ventilatory movements. Breath-by-breath analysis in real time is possible by a parallel processing of the transducer signal by the Analog/Digital Computer combination. The Analog program generates pulses at important events in the ventilatory cycle. The transducer signal and the pulses are monitored by a PDP-12 digital computer located off-site and linked via hard lines. The digital computer completes the analysis by indexing the breaths and calculating the important intervals and volumes. A versatile statistical package has been developed to help in the analysis of the data. This system of information processing also has applicability toward Cardiovascular Physiology for studying Pressure Pulse Period and Amplitude

K. C. O'Kane, D. Stone, R. D. Tallman, Jr.

AN AUTOMATED SYSTEM FOR MORPHOMETRIC ANALYSIS OF CELLS

Medical morphometry is the study of the measurement of size and shape of organisms. Traditional manual methods for morphometric analysis of microphotographs of cells are slow and tedious. A computerized system is proposed for the automated analysis of such images. Techniques include both statistical point-count techniques on individual two-dimensional images and the construction of three dimensional models from adjacent tissue cross-sections. Problems of adequate resolution are attacked by computer merging of overlapped photographs of a tissue cross-section and the optical enlargements of cell subcomponents, such as the nucleus. Trade-offs between memory requirements and accuracy are addressed. The target system will permit rapid derivation of volume, surface, and spacial distribution of all components. Such a system will be useful as a research tool and as a diagnostic test for some diseases such as cancer. Typical applications include identification of cell pathologies as a result of chemical or mechanical stress.

K. C. O'Kane, E. A. Haluska, D. J. Lim (Sponsor: National Library of Medicine. Grant LM 00159)

COMPUTER ANALYSIS OF SPINAL CORD BLOOD FLOW DATA

Regional blood flow is often used as a measure of spinal cord function in laboratory experiments. An interactive PL/1 program has been developed in

conjunction with the Neurosurgical Research Laboratory to facilitate calculation of this quantity by radioisotopic means (C labeled antipyrine). Dye is injected into the vena cava of monkeys, and monitored with a densitometer. Discrete point readings from the densitometer are then entered into the program to reconstruct the curve, and an integration is performed to determine the cardiac output.

Measured counts per minute from a gamma scintillation counter are entered into the program for control, blank and tissue tubes. The program then calculates tissue isotope concentration per gram of tissue from the derived disintegrations per minute (DPM). A summary printout of blood flow at each of 31 separate spinal cord and brain sites is then provided. This program has proved to be extemely useful to the Spinal Cord Injury Center in their investigations of mechanisms of cord trauma, and has eliminated manual estimation of the viability of the tissue.

K. C. O'Kane, B. K. Pflug,

A COMPUTER PROGRAM, UTILIZING NUMERICAL TAXONOMY AND DISCRIMINANT ANALYSIS TECHNIQUES FOR CATEGORIZATION OF HIGH RISK PREGNANCIES DURING THE FIRST TRIMESTER

A computer assisted method for categorization of pregnancies during the first trimester of pregnancy (the first 13-14 weeks) is proposed. The method applies numerical taxonomy and discriminant analysis techniques to numerous results from the laboratory, physical findings and historical information collected during the first trimester of pregnancy. The application of these techniques allows for categorization of patients into two major categories: those who will have a normal pregnancy, and those who will become or are at high risk. The identification of these high risk pregnancies will allow for more extensive and careful follow-up. The method will be applied to prenatal data from approximately 1500 patients.

K. C. O'Kane, E. E. McColligan (Sponsor: National Library of Medicine. Grant LM 00159)

A COMPUTER SIMULATION OF MAINTAINING TOTAL HEART LUNG BYPASS FOR BASIC EDUCATION

An interactive computer program was authored in BASIC to simulate normothermic total heart lung bypass. The in tructor may initiate a normal or disrupted set of arterial and venous pH's and blood gases with accompanying plasma bicarbonate base excess and hematocrit. The student then enters the conversational program and manipulates the simulated patient's pH's and gases back to normal ranges by altering variables such as oxygen and carbogen gas flows, blood flow, hematocrit and plasma bicarbonate level. Mathematical statements were created to predict the partial pressures of oxygen and carbon dioxide employing a physiological model. Other blood gas constituents were predicted with existing formulae. The simulation is flexible enough to mimic

CO_2 and O_2 limited oxygenators and patients with varying levels of oxygen consumption.

K. C. O'Kane, J. B. Riley (Sponsor: National Library of Medicine. Grant LM 00159)

CONTINUOUS MONITORING OF CARDIAC OUTPUT BY TRANSTHORACIC IMPEDANCE

The goal of this research is the continuous monitoring of cardiac output by the transthoracic impedance method. Continuous monitoring using transthoracic impedance is presently impractical due to the noncardiac related signal contaminants. These contaminants are primarily respiration related and signal noise.

Digital frequency domain techniques are being investigated to clean the impedance signal. The frequency spectrum of the transthoracic impedance signal in a group of clinically normal males has been characterized prior to the application of more sophisticated frequency domain techniques. This frequency analysis was performed using an interactive spectral analysis program. Future effort will be directed to spectral cleaning by frequency domain regression on noise and truncation of Fourier series.

K. C. O'Kane, J. W. Smith (Sponsor: National Library of Medicine. Grant LM 00159)

VII. MATHEMATICAL TECHNIQUES

BINARY STRINGS AND GEOMETRY

Last year under the title "Binary Strings & Topology," emphasis began to shift to the relation between a geometric reality and the formal languages used to describe them, i.e. the translation problem. This year the converse problem of multiple geometric realities describable by the same formal language was addressed by means of a specific case. In particular a binary language earlier devised for straight lines was investigated anew in an attempt to devise one for parabolas. Such a language, for the cartesian plane, was found, but it lacked the transparent logical structure of the original straight line language. When a transformation from cartesian to confocal parabolic coordinates was made, however, families of confocal coaxial parabolas had the same codes as a family of parallel lines in the original cartesian coordinate system. This is but one of an infinitude of similar cases where conformal mappings of the plane transform straight lines into general analytic curves (the conformal group is a very important subgroup of the group of topological mappings with many applications in physics and engineering). The possibility of solving problems in those areas by parallel computation on bus automata has now become realistic.

J. Rothstein

CLASSIFYING HARD PROBLEMS IN THE POLYNOMIAL HIERARCHY

We have demonstrated several techniques for showing that many optimization problems, including the symmetric Traveling Salesman Problem, the Chromatic Number Problem, and the Maximum Clique Problem are in Δ_2^p of the Polynomial Hierarchy, and not in NP or $co\text{-}NP$ unless $NP = co\text{-}NP$. This indicates that we need both positive and negative information from the oracle in NP to solve those problems in deterministic polynomial time, if $NP \neq co\text{-}NP$. These results can be extended to the Δ_k^p level of the hierarchy for all $k>1$.

A problem of some interest and importance is to determine whether Δ_2^p is a proper subset of Σ_2^p Π_2^p. The most obvious approach is to generalize some problem like PRIMES. However useful notions of generalization are not available, and thus their properties are not well studied. We are trying to fill this void.

D. Moore, E. W. Leggett

DELETIONS IN ONE-SIDED HEIGHT-BALANCED TREES

A one-sided height-balanced tree is a binary tree in which every node's right subtree has a height which is equal to or exactly one greater than the height of its left subtree. It has an advantage over the more general AVL tree in that only one bit of balancing information is required (two bits are required for the AVL tree).

It is shown that deletion of an arbitrary node of such a tree can be accomplished in $O(\log n)$ operations, where n is the number of nodes in the tree. Moreover, the method is optimal in the sense that its complexity cannot be reduced in order of magnitude. This result, coupled with earlier results by Hirschberg, indicates that of the three basic problems of insertion, deletion and retrieval, only insertion is adversely affected by this modification of an AVL tree.

S. H. Zweben, M. A. McDonald

DESIGN AND ANALYSIS OF EFFICIENT ALGORITHMS FOR UNCONSTRAINED MINIMIZATION

One of the most successful classes of algorithms for unconstrained minimization is the hybrid methods which consider the gradient direction of the objective function, the quasi-Newton direction or a convex combination of both. An efficient hybrid algorithm has already been developed which uses Davidson's 1975 optimally conditioned update to generate the quasi-Newton direction. Test results on 4 standard functions have been very promising and research will continue to reduce storage requirement, make the algorithm even better and analyze its convergence behavior.

H. H. Mei

NUMBER TREES, SEMIGROUPS, AND FORMAL LANGUAGES

The ϕ-tree has continued to monopolize the time available for this research (the ϕ-tree is a directed tree whose modes are labeled by all the positive integers, with a directed edge from N_1 to N_2 iff $\phi(N_1) = N_2$, ϕ is the Euler function). The concept of the "ϕheight" of an integer on the ϕ-tree, h, was introduced, along with the classes $H(h)$, the number of integers of height h. We define h as the number of iterations of ϕ needed to reduce an integer N to 2, $h=h(N)$. The function $H(h)$ is an irregular number theoretic function, but it goes to infinity with h "approximately" exponentially. We have proved that multiplying an integer by 2^k raises its height by k if it is even, by $(k-1)$ if it is odd, that the smallest even number of height h is 2^{h+1}, so that all numbers of $H(h)$ smaller than 2^{h+1} are odd. The ϕ-tree is "almost isomorphic" to an infinite number of its sub-trees; more explicitly note that for all integers N the subtree of integers $2^n N$, i.e. the integers with heights uniformly increased by n, we have preservation of all edge relations. The

meaning of "almost" is first that the odd leaves of the original tree are represented by their co-ϕ doubles, and second, primes of the form $2^n N+1$, which are leaves of the new subtree, must feed into $2^n N$ even though N is a leaf, for odd N, of the original tree.

J. Rothstein.

SELF-SOLVING QUASIGROUPS

The practical possibilities of these systems for cryptographic purposes were explored, culminating in the work abstracted under the title "Parallel Processable Cryptographic Methods with Unbounded Practical Security" to which the reader is referred for additional information. Self-solving quasigroups are sets closed under a binary operation (which we denote by concatenation) satisfying $ab = c$ implies $a = bc$. The only groups with this property have been shown to be direct products of cyclic groups of order 2. A self-solving quasigroup can be associated with an arbitrary group $(G,*)$, where $*$ is the binary operation of the group, by defining $ab = c^{-1}$ whenever $a*b = c$. Many self-solving quasigroups exist not related to groups in this way (e.g. Steiner quasigroups).

J. Rothstein

TREE PERMUTATIONS

There areseveral classes of permutations of n distinct elements which have nice relationships to binary trees containing n nodes. For example, if p is a permutation of n distinct elements $1,\ldots n$, then the number of such permutations for which there is no subsequence $p_i p_j p_k$ of p such that $p_k<p_i<p_j$ is exactly the number of binary trees containing n nodes. Moreover, the same result holds for any permutation of $p_i p_j$, and p_k in the condition "$p_k<p_i<p_j$". For four of these six permutations, the correspondence can be given using well-known methods of binary tree traversal. But the two permutations "$p_i<p_j<p_k$" and "$p_k<p_j<p_i$" do not have such a simple, direct correspondence.

An algorithm is developed which appears to give a direct relationship for the latter using the natural correspondence of binary trees to forests. The algorithm is being refined and a proof of its correctness investigated.

S. H. Zweben

VIII. SYSTEMS PROGRAMMING

CHARACTERIZATION AND EVALUATION OF DATA BASE SYSTEMS

Data base system performance depends in large part on the information structure of its data base and upon the characteristics of the user generated query stream. The goals of this research are:

1. To develop procedures for characterizing the information structure and user query stream of data base systems, and

2. To develop measures for evaluating the performance of data base systems as a function of the information structure and user query stream characteristics.

A procedure called attribute analysis has been developed to characterize the information structure. Another procedure for characterizing the user queries in terms of relational calculus type of expressions has also been developed. The methodology is being implemented using the Information Processing System Simulator (IPSS). The methodology will be applicable in the performance evaluation of both conventional information storage and retrieval systems and relational data base management systems.

T. G. DeLutis and P. M. K. Wong (Sponsor: National Science Foundation. Grant SIS-75-21648)

A COMPUTER GRAPHICS SCULPTORS' STUDIO

A major problem in three-dimensional computer graphics is that of making available to the computer descriptions (or "models") of complex objects in a form suitable for various graphics manipulations. In this research, we have aimed at creating a sculptors' studio-like environment in which the "sculptor" can create complex three-dimensional objects in the computer, as if molding a piece of clay in the machine. This calls for an array of techniques to be implemented and available at call to the user: scaling, slicing, gouging, joining objects, cutting one object with another 3-D warping and smoothing. The emphasis throughout is on naturalness and habitability.

Another important design consideration is compatibility with animation requirements. We have also added ability to specify color for the objects and the system is interspaced with a video display. A number of complex objects have been created and animation sequences have been made.

B. Chandrasekaran, R. Parent (Sponsor: National Science Foundation. Grant DCR 74-00768)

COMPUTER SECURITY, PRIVACY AND PROTECTION: A CROSS-REFERENCED, ANNOTATED BIBLIOGRAPHY

The individual interested in obtaining information on computer security, privacy or protection is faced with a difficult, time consuming task. An abundance of material is to be found in a wide variety of sources. To reduce the amount of work necessary for an interested individual, a cross-referenced bibliography of books, technical reports and papers on computer security, privacy and protection published since 1973 will be produced. Annotations of the more important papers studied will be included.

The bibliography will also contain a summary of the recent work in computer security, privacy and protection in which we analyze the state of the art and provide some insight into what problems remain unsolved.

D. S. Kerr, P.F. Sherburne (Sponsor: Office of Naval Research. Grant: N00014-67-A-0232-0022)

CORRECTNESS OF PROGRAM TRANSFORMATIONS BASED ON AXIOMATIC SEMANTICS

Transformations provide a way to reliably modify a program from a form that may be readable or easily proved correct, into a form that is more efficient for execution by machine. In this research various program transformations are being examined and in particular they are being proved correct.

The semantics of the language in which the transformations are given, are specified axiomatically. Hence, the transformations are shown correct in the sense that from a proof about an untransformed program a proof about the transformed program may be derived.

B. Russell

THE DESIGN OF A SECURE COMPUTER SYSTEM

This research is concerned with the design of a secure computer system. Security and protection in the system is achieved by a unified application of cryptography, access control and special procedures that improve either the security of the system or its operational efficiency. In addition, multi-level sharing of information is also provided in the system, viz., no sharing at all, sharing of programs and data, sharing of programming subsystems, and cooperation of mutually suspicious subsystems. Other factors considered in the design are generality, completeness, hardware implementation, flexibility and efficiency.

The components of the system and its corresponding operation to be protected are: 1) remote terminals for communication with remote users, 2) communication lines for data transmission, 3) main memory for data processing, and 4) external files for data storage and retrieval. A brief description of

the operation, verification and evaluation of the secure computer system is also given.

M.T. Liu, S. Muftic

DESIGN OF EVENT-DRIVEN PROTECTION MECHANISMS

The goal of this research is the development of a new type of protection mechanism which can provide a higher level of data sharing in interactive data secure systems. In all currently known protection mechanisms, access control decisions are made a priori on the basis of access rules related to users, data resources, and data base operations. In this research, an attempt is made to include protection mechanisms in which access decisions depend upon additional factors such as past access history and system's data.

The results show that a protection mechanism, which uses past access history information in its access decisions, can enforce specific patterns of data base operations on one hand and can provide derivation protection on the other. This means that an event sensitive protection mechanism can be utilized to provide information protection.

The model developed suggests a new approach to the implementation of distributed protection mechanisms in distributed data base systems.

M. T. Liu, D. Cohen

EARLY RUN TIME ESTIMATION

The prediction of the processing time required to run a given production job on a specific hardware/software configuration is an important performance question. The "early run time estimation" is required to evaluate whether or not a proposed production job can be added to the workload of an existing system. This work proposes to apply a statistical methodology called signature table analysis to the early run time estimation problem, in an effort to predict processing time based on the proposed production job characteristics, within a stated level of statistical confidence or probability of correctness.

S. A. Mamrak, P. Amer

EXPERIMENTAL MEASUREMENT OF PROGRAM EFFICIENCY

With structured programming practices becoming widespread, it seems likely that increasing emphasis may be placed on computing system resource utilization to gain additional efficiencies. This potential exists particularly for tradeoffs among control structures and their language implementation in programming for a particular problem. While analytic procedures exist for calculating run times, differences in compilers as well as computer systems suggest that experimental measurement might be a useful adjunct to analytic estimation. This research reports preliminary research conducted along these lines. Variations in programs using different control structures to achieve the same problem solution were written in ALGOL as a target language, and in similar FORTRAN and PASCAL programs. Run times were measured for each variation and were compared with each other and with analytic

calculations. Differences were found among structures and analytic calculations. These departures are discussed in terms of control structures, programming language conventions, and system characteristics. The approach appears promising as part of a human factors package for program writing and development.

R. L. Ernst, P. S. Wang

A FEATURE SELECTION TOOL FOR WORKLOAD CHARACTERIZATION

A representative test workload is required for various computer system performance evaluation activities. The two critical issues in generating representative test workloads are i) the definition of the performance variables which are to be used to characterize the workload and ii) the development of an appropriate technique for test workload generation that provides a metric to quantitatively describe the "distance" between the real and test workloads. While some particularly useful approaches to the second problem have been developed (workload characterization based on the joint probability distribution of system resource demands and workload characterization based on the clusters or classes of jobs which make similar system resource deands), little attention has been paid to the selection of the performance variables or job "features" upon which the characterization is based.

In the case of characterizing computer workloads, a wide range of measurements indicating various types of research demands have been considered to be important for job classification. Though this set of available features is relatively large, in practice the maximum number of features used for workload characterization is usually constrained. The set of all possible resource demand measurements must therefore be evaluated and only the most effective ones chosen. This paper describes the application of a feature selection technique which generates reduced feature subsets while minimizing the probability of misrecognition of job classifications based on the new subset . The feature selection algorithm is a nonparametrical method which incorporates a backward sequential selection process to eliminate features one by one. An experimental application of the methodology is presented, along with an interpretation of the results in light of the actual system and user population, and a discussion of the general merits of the technique.

S. A. Mamrak, P. Amer

A MODEL OF THE DISTRIBUTION OF OPERATORS IN COMPUTER PROGRAMS

Recent investigations into the rank-ordered frequency distributions of operators in computer programs have demonstrated conclusively that definite patterns exist which are repeated in a wide range of data. Yet it is also clear that none of the existing models is entirely satisfactory in explaining the observed operator distributions.

A new model of operator frequencies is developed using some basic principles of software science. The model shows a marked statistical improvement in fit over existing models when tested on a previously published set of data. More extensive experimental work is being done on the model, and refinements of

it are being investigated.

S. H. Zweben

PARALLEL PROCESSABLE CRYPTOGRAPHIC METHODS WITH UNBOUNDED PRACTICAL SECURITY

Cryptographic methods are described which, at reasonable cost to users, impose prohibitive work penalties on code-breakers. The class of cryptographic transformations is so vast that codes can be used once and discarded, both in communication and in data security applications. We use the groupoid string formalism (earlier shown to combine Turing universality with parallel computing capability) specialized to quasigroups for unique decodability. Coding for error detection and correction can be done compatibly and independantly. It appears likely that crypto and reliability encoding can be systematically combined to decoy code-breakers into semanticizing their decoding of reliability procedures into message opacifiers. Identification, authorization, and handshaking procedures can be integrated into the cryptographic method (with total update capability) at incremental user cost comparable to separate cost of those procedures or less.

J. Rothstein

REFINEMENT OF A DEFINITIONAL INTERPRETER

One way of defining a programming language is to provide an interpreter for the language. This interpreter will be abstract in the sense that it will not be run on a machine but rather is intended to be read by humans.

Once such an abstract interpreter has been defined a process known as refinement may be applied to it with the aim of improving the efficiency of the interpreter. This goal of this research is to see to what extent various representations for programs such as flow charts and machine languages, or ways of implementing various features, such as thumbs for name parameters and closures for functions follow as a consequence of the refinement process.

B. Russell

SOFTWARE REQUIREMENTS OF A DATABASE COMPUTER

As a part of continuing research on database machines, this work is directed towards a study of the software requirements for implementing existing data models on a database computer (DBC). The DBC is a back-end machine with advanced information handling, record clustering and access control mechanisms. Its interfaces to user programs are still implemented in front-end computers, such as IBM 370. This research work investigates the software requirements on the front-end machine to support a network data model. In particular, the CODASYL data definition and data manipulation features have been singled out for study. It has been observed that there is a significant improvement in performance when the DBC is used in place of a conventional CODASYL-like data management software system. More specifically, there is a ten to hundredfold improvement both in secondary storage access time and in directory memory requirement. Moreover, the advanced features of the DBC can be used to support security mechanisms better than what is provided in existing network databases.

D. K. Hsiao, J. Banerjee (Sponsor: Office of Naval Research N00014-75-C-0573)

STATISTICAL METHODS FOR COMPARISON OF COMPUTER SERVICES

A computer comparison methodology based on statistical ranking and selection techniques is described as it can be applied to the selection of the best computer service. The selection criterion among the computer systems is either the lowest mean measurement or the lowest quantile measurement of an appropriate performance descriptor. Essentially, the ranking and selection techniques indicate the number of measurements or observations which must be made on each system to ensure a large enough probability of having made a correct choice. Experimental data from a case study are used to illustrate and clarify the correct application of the methodology.

S. A. Mamrak, P. DeRuyter

A TAXONOMY FOR VALID TEST WORKLOAD GENERATION

A test workload which adequately represents a real system workload is required for various computer performance evaluation studies. The valid generation and use of a benchmark is affected by the particular evaluation environment in which the benchmark is to be used. A taxonomy of test environments is developed in this research, along with a specification of which test workload generation methods are valid in each evaluation context. The taxonomy is useful for classifying previous workload generation work, for evaluating current workload generation efforts, and for identifying test environments in which further research is required. The primary impact of the taxonomy is the clear identification of the relatively small number of evaluation environments in which valid workload generation methodologies have been developed. A methodology based on statistical pattern recognition techniques is proposed as the best candidate for a general solution to the workload characterization problem in most evaluation environments.

S. A. Mamrak, The Ohio State University; M. D. Abrams, National Bureau of Standards.

IX. COMPUTER ARCHITECTURE AND NETWORKS

COMPARING EQUIVALENT NETWORK SERVICES THROUGH DYNAMIC PROCESSING TIME PREDICTION

Computer networks provide the potential for resource sharing. Realization of this potential requires knowledge of the available resources within the network. Moreover, if a given resource is available at more than one host, selection of the most appropriate host is required. This research develops a dynamic means for host selection assuming that the evaluation metric is processing time. An experiment is described which provides an initial evaluation of the key component of the methodology on two separate systems. The paper concludes with a discussion of some overall insights into the applicability of the methodology and its implementation requirements.

S. A. Mamrak, The Ohio State University, S.R. Kimbleton, The National Bureau of Standards

CONTROL AND COMMUNICATION IN DISTRIBUTED PROCESSING

This research is concerned with control and communication issues in distributed processing. Distributed processing means here to support sharing and distributing program and data modules of a single application program among processors on a work unit at the task or subroutine level. Different modules can run at different sites within the system in order to take advantage of any specialized resources that may be available there. In particular, a model is proposed for distributed processing which is based on interactions among independent processes. This model generalizes the hierarchical structure which is traditionally used as the model of control and which forces a parent-son relationship between processes. Rather, the model is built on independent processes which co-exist within the system on an equal status. Communication among the processes are effected by explicit exchange of messages through the communication path established by the interprocess communication mechanism supported by the system. Facilities are also provided for synchronization and communication among the processes. Furthermore, the traditional hierarchical control structure can be easily simulated as a special case of this general model.

M. T. Liu, L. M. Ma

THE DISTRIBUTED LOOP COMPUTER NETWORK (DLCN)

Conceived as a means of investigating fundamental problems in distributed processing and local networking, the Distributed Loop Computer Network (DLCN) is envisioned as a powerful distributed computing system which interconnects

midi, mini and micro-computers, terminals and other peripheral devices through careful integration of hardware, software and a communication channel. The network is constructed in such a manner that its users will see a single, integrated computing facility with great power and many available resources without being aware of the system's actual organization and method of operation.

System design of DLCN has been mainly in four areas. Firstly, for the loop communication subnet, a novel message transmission mechanism has been developed, its implementation in the loop interface hardware treated, and its superior performance verified by queueing analysis and GPSS simulation. Secondly, a bit-oriented, distributed message communication protocol (DLMCP) which handles four message types under one common format has been proposed. Besides user information transfer, this protocol supports automatic hardware-generated message acknowledgement, error detection and recovery, and network control and distributed operating system functions. Thirdly, the network operating system (DLOS) has been designed to provide facilities for interprocess communication by process name, remote program calling, generalized data transfer, process control structures, distributed resource management and logical I/O transmission in a distributed data base system. Finally, a network command language is provided to the user for easy and uniform access to the network resources, and for concurrent and distributed processing of his applications.

With these many features, it is hoped that DLCN can realize its goal of becoming a powerful, unified distributed computing system.

M. T. Liu, C. C. Reames, L. M. Ma, G. Babic, R. Pardo, Y. Oh, A. T. Teng, E. A. Potter

METHODOLOGY FOR COMPUTER PROGRAM TESTING

In this research, we are concerned with the problem of testing computer programs. Several theoretical issues need to be understood thoroughly before practical and reliable software validation systems can be built. One major class of program errors concerns domain errors, i.e., those errors which result from incorrect predicates in branch statements and which cause the program to follow incorrect control flow paths for some inputs. We outline a new strategy to test for domain errors with almost complete reliability by using only a finite number of test points, for linear predicates and a class of nonlinear predicates. We propose further theoretical research into reducing the complexity of this strategy to make it practical for moderately large input space dimensionality. It appears that a careful study of the order of paths selected for testing and of use of results from paths tested earlier would lead to significant economies.

L. J. White, B. Chandrasekaran, E. Cohen (Sponsor: Air Force Office of Scientific Research. Grant 77-3416)

TRAFFIC ANALYSIS OF THE DISTRIBUTED LOOP COMPUTER NETWORK (DLCN)

This research is concerned with traffic analysis of a distributed loop communication network which uses a novel shift-register insertion mechanism for message transmission. This new mechanism allows simultaneous multiplexing of multiple variable-length messages onto the loop, and thus yields shorter message delays and makes better utilization of the channel than any existing transmission mechanism. An analytical model of the loop network is first developed. An approximate analytical technique is then used to obtain a simple and efficient method for calculating channel utilization and average message delay. This technique is applied to a symmetric loop with identical nodal characteristics and to an asymmetric loop with different nodal characteristics. Finally, simulation was carried out on an IBM 370/168 using GPSS/360 to verify the analytical results. It turns out that the analytical and simulation results agree very closely, especially in the range under light traffic.

M. T. Liu, G. Babic, R. Pardo (Sponsor: Air Force Office of Scientific Research. Grant 221110)

X. COMPUTATION THEORY

TOWARD AN ARITHMETIC FOR CELLULAR AUTOMATA AND PARALLEL COMPUTATION

A paper in progress with the above title has been accepted on the program of the International Conference on Parallel Processing, August, 1977, and the paper will appear in the proceedings. Its abstract is as follows.

A new positional binary number system was devised in an attempt to avoid carrying in addition. It originated from the groupoid string formalism, previously shown to have the computation universality of Turing machines and the parallel capabilities of cellular and bus automata. It is uniquely defined by the natural conditions (a) a number is doubled by adding a copy, where digits are added mod 2, and (b) adding 1 to any number adds 1 mod 2 at precisely one place. Arithmetical, combinatorial, and parallel computational properties of the system are discussed.

J. Rothstein

XI. JOINT PROGRAMS

COMPUTER SCIENCE FACULTIES: THE CURRENT STATUS OF MINORITIES AND WOMEN

The results of a survey conducted in the fall of 1975 to determine the status of women and minority faculty members in academic computer science are presented. Faculty members were compared with respect to professional background, salaries, teaching load, publication records, and research grants. Analysis of the data indicated that the over-all verdict is one of general equality among women, minorities, and men.

S. A. Mamrak, The Ohio State University, R.G. Montanelli, University of Illinois

APPENDIX A

GROWTH OF DEPARTMENT OF COMPUTER AND INFORMATION SCIENCE

	SEPT'72	SEPT'73	SEPT'74	SEPT'75	SEPT'76	SEPT'77
A. Staff						
1. Full Time	18	18	20	21	22	20
2. Part Time	14	16	12	12	12	13
B. Graduate Students	187	209	198	201	182	197
C. Undergraduate Students	450	510	475	450	470	470(est)
D. Course Enrollment (Autumn Quarter)	1676	1728	1925	2098	2290	2424

	'72-'73	'73-74	'74-75	75-76	'76-77	'77-78
Students Taught	5600	6129	6876	7241	7615	8402
Baccalaureate Degrees Awarded	118	139	109	103	118	
M.S. Degrees Awarded	49	67	58	64	70	62(est)
Ph.D. Degrees Awarded	8	4	7	13	5	13(est)
Applications for Graduate Study	323	290	355	325	333	
Number of Graduate Students Supported	83	78	81	77	81	

APPENDIX B

COMPUTER AND INFORMATION SCIENCE COURSE LISTING

BY NUMBER AND TITLE

100 Computers in Society

201 Elementary Digital Computer Programming

211 Computer Data Processing I

212 Computer Data Processing II

221 Programming and Algorithms I

222 Programming and Algorithms II

294 Group Studies

294A/223 Introduction to Computer Systems

311 Introduction to File Design and Analysis

411 Design of On-Line Systems

505 Fundamental Concepts of Computer and Information Science

509 Survey of Computer and Information Science for High School Teachers

541 Survey of Numerical Methods

542 Introduction to Computing in the Humanities

543 Intermediate Digital Computer Programming

548 Computer Science for High School Teachers

549 Numerical Analysis for High School Teachers

550 Introduction to Information Storage and Retrieval

555 Survey of Programming Languages

610 Principles of Man-Machine Interaction

640 Numerical Analysis

641 Computer Systems Programming I

642 Numerical Linear Algebra

643 Linear Optimization Techniques in Information Processing

644 Advanced Computer Programming

675 Digital Computer Organization

676 Minicomputer and Microcomputer Systems

677 Computer Networks

680 Data Structures

693 Individual Studies

694 Group Studies

694 A - Interactive Computer Graphics

694 C - Mini-Computer Programming Laboratory

694 D - The Technology of Computer Center Management

694 E - An Introduction to Data Communication Systems

694 F - Principles of Operating Systems

694 I - Fundamentals of Business Computer Systems and Programming

705 Mathematical Foundations of Computer and Information Science

712 Man-Machine Interface

720 Introduction to Linguistic Analysis

726 Theory of Finite Automata

727 Turing Machines and Computability

728 Topics in Theory of Computing

730 Basic Concepts in Artificial Intelligence

735 Statistical Methods in Pattern Recognition

740 Computer Systems Programming II

741 Comparative Operating Systems

745 Numerical Solution of Ordinary Differential Equations

746 Advanced Numerical Analysis

750 Modern Methods of Information Storage & Retrieval

751 Fundamentals of Document-Handling Information Systems

752 Techniques for Simulation of Information Systems

753 Theory of Indexing

754 Language Processing for Information Storage & Retrieval

755 Programming Languages

756 Compiler Design & Implementation

765 Management Information Systems

775 Advanced Computer Organization

780 File Structures

781 Aspects of Computer Graphics Systems

788 Intermediate Studies in Computer & Information Science

- 788.01 - Theory of Information
- 788.02 - Information Storage & Retrieval
- 788.03 - Theory of Automata
- 788.03A- Recent Advances in Algorithmic Complexity
- 788.04 - Artificial Intelligence
- 788.05 - Pattern Recognition
- 788.06 - Computer Systems Programming
- 788.06A- OS-MVT
- 788.07 - Programming Languages
- 788.08 - Computer Languages
- 788.09 - Numerical Analysis
- 788.10 - Man-Machine Interaction
- 788.11 - Formal Languages
- 788.12 - Management Information Systems
- 788.13 - Biological Information Processing
- 788.14 - Socio-Psychological Aspects of Information Processing

793 Individual Studies

797 Interdepartmental Seminar

805 Information Theory in Physical Science

806 Cellular Automata & Models of Complex Systems

812 Computer & Information Science Research Methods

820 Computational Linguistics

835 Special Topics in Pattern Recognition

840 Operating System Implementation

845 Numerical Solution of Partial Differential Equations

850 Theory of Information Retrieval I

852 Design and Analysis of Information Systems Simulations

855 Advanced Topics in Programming Languages

865 Seminar on Socio-Psychological Aspects of the Information Sciences

880 Advanced Theory of Computability

888 Advanced Studies in Computer & Information Science

888.01 - Theory of Information

888.02 - Information Storage & Retrieval

888.03 - Theory of Automata

888.04 - Artificial Intelligence

888.05 - Pattern Recognition

888.06 - Computer Systems Programming

888.07 - Programming Languages

888.08 - Computer Organization

888.09 - Numerical Analysis

888.10 - Man-Machine Interaction

888.11 - Formal Languages

888.12 - Management Information Systems

888.13 - Biological Information Process

888.14 - Socio-Psychological Aspects of Information Processing

889 Advanced Seminar in Computer & Information Science

894 Group Studies

899 Interdepartmental Seminar

999 Research

APPENDIX C

COMPUTER AND INFORMATION SCIENCE FACULTY

Marshall C. Yovits, Ph.D., (Yale University).
Professor and Chairman of Department of Computer and Information Science and Professor of Electrical Engineering. Director, C.I.S. Research Center. Information systems, theory of information flow and analysis, self-organizing systems, management information systems.

Ranko Bojanic, Ph.D., (Mathematical Institute of the Serbian Academy of Science).
Professor of Computer and Information Science and Professor of Mathematics. Mathematical analysis, theory of approximation.

Balakrishnan Chandrasekaran, Ph.D., (University of Pennsylvania).
Professor of Computer and Information Science. Pattern recognition, artificial intelligence, interactive graphics, finite memory decision theory.

Charles A. Csuri, M.A., (The Ohio State University).
Professor of Computer and Information Science and Professor of Art. Advancement of computer graphics technology in software and hardware (language algorithms, data generation or inputs), use of computer technology in telecommunications.

Richard I. Hang, M.A., (The Ohio State University).
Professor of Computer and Information Science and Professor of Engineering Graphics. Computer graphics, engineering application of computers.

Clyde H. Kearns, M.S., (The Ohio State University).
Professor of Computer and Information Science and Professor of Engineering Graphics. Computer graphics, engineering application of computers.

Robert D. LaRue, P.E., M.S., (University of Idaho)
Professor of Computer and Information Science and Professor of Engineering Graphics. Computer graphics, engineering applications of computers.

Robert B. McGhee, Ph.D., (University of Southern California).
Professor of Computer and Information Science and Professor of Electrical Engineering. Robotics, switching theory, logical design.

Harold B. Pepinsky, Ph.D., (University of Minnesota).
Professor of Computer and Information Science and Professor of Psychology. Counseling, socio-cultural psychology, language and social policy.

Roy F. Reeves, Ph.D., (Iowa State University).
Professor of Computer and Information Science and Professor of Mathematics. Director, Instruction and Research Computer Center. Numerical analysis, programming, computer center management.

Jerome Rothstein, A.M., (Columbia University).
Professor of Computer and Information Science and Professor of Biophysics. Information and entropy, foundations of physics, methodology, biocybernetics, automata theory, formal languages, cellular automata, parallel processing.

Charles Baltzer, Ph.D., (Brown University).
Professor of Computer and Information Science and Professor of Mathematics. Coding theory, numerical analysis, automata theory.

Kenneth Breeding, Ph.D., (University of Illinois).
Associate Professor of Computer and Information Science and Associate Professor of Electrical Engineering. Computer organization and switching theory.

H. William Buttelmann, Ph.D., (University of North Carolina).
Associate Professor of Computer and Information Science. Formal language theory, computational linguistics, language processing, programming languages.

Thomas G. Delutis, Ph.D., (Purdue University).
Associate Professor of Computer and Information Science. Methodologies for the design and evaluation of information processing systems, data base management systems architecture, simulation studies.

Ronald L. Ernst, Ph.D., (University of Wisconsin).
Associate Professor of Computer and Information Science and Associate Professor of Psychology. Man-computer interaction, decision-systems, general theory of human performance.

Clinton R. Foulk, Ph.D., (University of Illinois).
Associate Professor of Computer and Information Science. Systems programming, computers in education.

David K. Hsiao, Ph.D., (University of Pennsylvania).
Associate Professor of Computer and Information Science. Systems programming, computer architecture, data base management systems, access control and privacy protection of data, data base computers.

Douglas S. Kerr, Ph.D., (Purdue University).
Associate Professor of Computer and Information Science. Programming, data base systems, numerical analysis.

Ming-Tsan Liu, Ph.D., (University of Pennsylvania).
Associate Professor of Computer and Information Science. Computer architecture and organization, computer communications and networking, parallel and distributed processing, mini/micro computer systems.

Anthony E. Petrarca, Ph.D., (University of New Hampshire).
Associate Professor of Computer and Information Science. Automatic indexing, chemical structural information processing, automated search systems, other aspects of information storage and retrieval, biomedical information processing.

James B. Randels, Ph.D., (The Ohio State University).
Associate Professor of Computer and Information Science and Assistant Director, University Systems Computer Center. Computer operating systems and utilities, telecommunications applications, subroutine libraries, programming languages.

James E. Rush, Ph.D., (University of Missouri)
Adjunct Associate Professor of Computer and Information Science. Indexing theory, automated language processing, organization of information, parallel processing, structured programming, program testing and program management.

Celianna I. Taylor, B.S.L.S., (Graduate School of Library Science, Case-Western Reserve University).
Senior Research Associate and Associate Professor of Library Administration. Data base design (natural language data), information dissemination systems, information centers, library systems and management.

Lee J. White, Ph.D., (University of Michigan).
Associate Professor of Computer and Information Science and Associate Professor of Electrical Engineering. Algorithm analysis and complexity, data structures, organization of information.

Ronald L. Wigington, Ph.D., (University of Kansas).
Adjunct Assoicate Professor of Computer and Information Science and Director of R. & D., Chemical Abstracts Service. Computer and information system design.

Harvey S. Koch, Ph.D., (Pennsylvania State University).
Assistant Professor of Computer and Information Science. Data definition language, data base management, programming languages and compiler design.

Anthony P. Lucido, Ph.D., (Iowa State University).
Assistant Professor of Computer and Information Science. Computer architecture, compiler design, interactive computer graphics.

Sandra Mamrak, Ph.D., (University of Illinois).
Assistant Professor of Computer and Information Science. Computer system performance evaluation, computer networks, systems programming.

Howell H. W. Mei, Ph.D., (Cornell University)
Visiting Assistant Professor of Computer and Information Science. Nonlinear optimization, nonlinear systems of equations, operating systems design, algorithm design.

Daniel J. Moore, Ph.D., (University of Kansas).
Assistant Professor of Computer and Information Science. Complexity theory, recursion theory, semantics of simulation systems, formal theories of data abstraction.

Kevin C. O'Kane, Ph.D., (Pennsylvania State University).
Assistant Professor of Computer and Information Science and Assistant Professor of Allied Medical Professions. Coordinator, Graduate Training Program in Biomedical Computing and Information Processing. Biomedical computing, large medical data bases, clinical data acquisition, automated diagnosis.

Lawrence L. Rose, Ph.D., (Pennsylvania State University).
Assistant Professor of Computer and Information Science. Programming languages, information storage and retrieval, simulation, information theory.

Bruce Russell,Ph.D., (National University of Ireland).
Visiting Assistant Professor of Computer and Information Science. Formal semantics of programming languages and data structures, automatic generation of implementations, programming methodologies, theories of representations and automatic generation of representations from abstract definitions.

Norman K. Sondheimer, Ph.D., (University of Wisconsin).
Assistant Professor of Computer and Information Science. Natural language processing, artificial intelligence, information storage and retrieval.

Richard R. Underwood, Ph.D., (Stanford University). Appointed Autumn 1977.
Assistant Professor of Computer and Information Science. Numerical linear algebra, solution of large sparse systems of equations, eigenvalue analysis, linear least squares problems, numerical solution of differential equations.

Stuart H. Zweben, (Purdue University).
Assistant Professor of Computer and Information Science. Programming languages, programming methodology, data structures, analysis of algorithms, systems programming.

Ernest Staveley, B.S., (U.S.Naval Postgraduate School).
Administrative Assistant and Assistant Director, C.I.S. Research Center.

APPENDIX D

COMPUTER AND INFORMATION SCIENCE SEMINAR SERIES

September 30, 1976 "Recent Data Base Activities at IBM Research Laboratory, San Jose -- A Visitors Impression," David K. Hsiao, Associate Professor, Department of Computer and Information Science, The Ohio State University.

October 7, 1976 "Information and Computer Services at Shell Oil Company," David E. Pope, Manager, Chemical Products Systems Coordination, Shell Oil Company.

October 21, 1976 "From Structured Programs to Flow-Charts to Machine Language," Bruce D. Russell, Visiting Assistant Professor, Department of Computer and Information Science, The Ohio State University.

October 28, 1976 "The Use of Computers in Information Processing at Chemical Abstracts Service," Chuck Costakos, Assistant to Director of Research and Development, Chemical Abstracts Service.

November 4, 1976 "Strategy, Annual Reports, and Alchemy: The Minicomputer/Peripheral Industry," Edward H. Bowman, Dean and Professor of Management Sciences, College of Administrative Science, The Ohio State University.

January 20, 1977 "On the Ultimate Limitations of Parallel Processing*," Jerome Rothstein, Professor, Department of Computer and Information Science and Department of Biophysics, The Ohio State University.
*Best Paper Award, 1976 International Conference on Parallel Processing.

February 3, 1977 "Color Raster Scan Animation," Charles A. Csuri, Professor, Department of Art and Department of Computer and Information Science, The Ohio State University.

February 9, 1977 "Data Streams," M. Douglas McIlroy, Head, Computing Techniques Research Department, Bell Telephone Laboratories, Murray Hill, NJ.

February 16, 1977 "Representation and Computerization of Office Processes," Michael D. Zisman, Lecturer in Decision Sciences, The Wharton School, University of Pennsylvania.

February 24, 1977 "Computer Graphics using a Plasma Panel," Richard I. Hang, Professor, Department of Engineering Graphics and Department of Computer and Information Science, The Ohio State University.

March 1, 1977 "Investigation of Differential Equations Using Interactive Graphics," R. Leonard Brown, Assistant Professor, Department of Applied Mathematics and Computer Science, The University of Virginia.

March 3, 1977 "Microprocessors -- Fun and Games with Today's Technology," Fred Hatfield, President, Computer Data Systems, Inc.

April 7, 1977 "Large Systems on Small Computers," Jeffrey Jalbert, Associate Professor, Department of Physics, and Director, Computer Center, Denison University.

April 14, 1977 "Quasi -- Newton Methods for Tuning up you Car," Howell H. W. Mei, Assistant Professor, Department of Computer and Information Science, The Ohio State University.

April 21, 1977 "A Semantics for Computer Simulation Models," Daniel J. Moore, Assistant Professor, Department of Computer and Information Science, The Ohio State University.

April 27, 1977 "On Very Hard Heuristic Algorithms," Lawrence T. Kou, IBM Research Center.

May 5, 1977 "A Validation of a Computer-Based Text-Reading Program," Thomas W. Milburn, Mershon Professor of Psychology and Public Policy, The Ohio State University.

May 9, 1977 "Design of a Highly Parallel Computer for Raster Picture Processing and Graphics," Carl F. R. Weiman, Professor, Department of Mathematics and Computing Sciences, Old Dominion University.

May 12, 1977 "Database Abstractions: Aggregation and Generalization," Diane C. P. Smith, Assistant Professor, Department of Computer Science, University of Utah.

May 26, 1977 "Computer-Assisted Sound Synthesis and Musical Composition," Gary Nelson, Associate Professor, Department of Music, Oberlin College Conservatory of Music.

May 27, 1977 "On the Four-Color Problem," W. Haken, Professor, Department of Mathematics, University of Illinois.

June 20, 1977 "Application of Linear Programming Methods to Graph Theory," Michael Clancy, Professor, Department of Computer Science, Stanford University.

June 23, 1977 "Report on NCC 77," Marshall C. Yovits, Chmn.; David K. Hsiao, Associate Professor: and Stuart H. Zweben, Assistant Professor, Department of Computer and Information Science, The Ohio State University.

June 30, 1977 "New Developments in the Solution of Large Systems of Linear Equations," Richard Underwood, Nuclear Energy Systems Divison, General Electric Company, San Jose, CA.

APPENDIX E

RELATED ACTIVITIES OF THE DEPARTMENT OF COMPUTER AND INFORMATION SCIENCE

T. Augustyn presented a paper entitled "A Medically Oriented Data Access Language" (Co-author: K. C. O'Kane) at the Association for Computing Machinery Computer Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

W. F. Buttelmann presented a paper entitled "Some Properties of Arbitrary Phrase Structure Languages and Translation Derived Using a Formal Model of Phrase Structure Syntax and Semantics" at the Fifteenth Annual Meeting of the Association for Computational Linguistics, Georgetown University, March 16-17, 1977.

J. S. Chandler presented a paper entitled "A Methodology for Multi-Criteria Information System Design" (Co-author: T. G. DeLutis) at the Association for Computing Machinery Computer Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

B. Chandrasekaran presented an invited paper entitled "Moulding Computer Clay - Steps Towards a Computer Graphics Sculptors' Studio" (Co-author: R. E. Parent) at the Workshop on Pattern Recognition and Artificial Intelligence, Cape Cod, Massachusetts, June 2, 1977.

B. Chandrasekaran presented a paper entitled "On Balancing Decision Functions" (Co-author: A. K. Jain) at the International Information Theory Symposium, Ronneby, Sweden, June 21-24, 1977.

B. Chandrasekaran continues as editor for artificial intelligence and pattern recognition for the IEEE Transaction Systems, Man and Cybernetics.

B. Chandrasekaran reviewed proposals for the National Science Foundation and, the Air Force Office of Scientific Research during 1976-77.

B. Chandrasekaran has been appointed book review editor of the Newsletter of the Society for the Interdisiplinary Study of the Mind.

B. Chandrasekaran was an Honorable Mention winner of the Second Annual Pattern Recognition Society Award for his paper entitled "A Heuristic Strategy for Developing Human Facial Images on a CRT" (Co-author: M. L. Gillenson) published in Pattern Recognition, 1975.

R. L. Ernst presented a paper entitled "Experimental Measurement of Program Efficiency" (Co-author: P. S. Wang) at the Association for Computing Machinery Computer Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

E. Gudes presented a paper entitled "The Application of Cryptographic Transformations for Data Base Security" (Co-authors: H. S. Koch and F. A. Stahl) at the National Computer Conference, New York City, June 8, 1976.

E. Haluska presented a paper entitled "An Automated System for Morphometric Analysis of Cells" (Co-author: K.C. O'Kane) at the Association for Computing Machinery Computer Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

D.K. Hsiao founded the Very Large Data Base Conferences Foundation and initiates the Very Large Data Base Conferences. The first conference was held at Boston, Massachusetts, September, 1975; the second conference was held at Brussels, Belgium, September, 1976; the third one was held at Tokyo, Japan, October, 1977; and the fourth one will be held at West-Berlin, Germany, September, 1978.

D.K. Hsiao initiated a quarterly journal for the Association for Computing Machinery entitled ACM Transactions on Database System (TODS), beginning January 1976. He currently serves as Editor-in-chief of this journal.

D.K. Hsiao presented a paper entitled "A Semantic Model for Data Base Protection Languages" (Co-author is R. Hartson of Virginia State University) at the Second International Conference on Very Large Data Bases, Brussels, Belgium, September 8-10, 1976. The paper appears in Systems for Large Data Bases, E.J. Neuhold and P. Lockemann, editors, North-Holland, 1976.

D.K. Hsiao presented his experimental work on data secure systems in a session and chaired another session at the 2nd International Conference on Software Engineering, San Francisco, California, October 13-15, 1976.

D.K. Hsiao presented an invited talk on Database Computers at a Joint Electrical Engineering - Computer Science Colloquium, Purdue University, Lafayette, Indiana, December 8,1976.

D.K. Hsiao attended the IEEE Computer Society's Governing Board Meeting in San Francisco, California, March 3-4, 1977, and was appointed to the Nomination Committee which is responsible for recommending new governors for 1978-1979.

D.K. Hsiao organized the first workshop concerned with interfaces between databases and operating systems, entitled The IEEE Workshop on Operating and Database Management Systems, The first workshop was at Evanston, Illinois, March 21-22, 1977. At this workshop, Dr. Hsiao also chaired a round-table discussion on future issues of related research.

D.K. Hsiao was elected to Senior Membership in the IEEE, effective April, 1977.

D.K. Hsiao presented an invited talk entitled "The Design and Performance of a DataBase Computer" at the IBM Research Laboratory, San Jose, California, May 12, 1977.

D.K. Hsiao served a a panelist on "Data Base Management and Future" at the National Computer Conference, Dallas, Texas, June 15, 1977.

D.K. Hsiao was appointed to the Governing Board of the IEEE Computer Society, December 1976-December 1978.

D. L. Kalmey presented a paper entitled "Potentially Nonconvergent Regions Inherent in Systems of Nonlinear Equations" (Co-authors: D.S. Kerr and L.J. White) at the Society for Industrial and Applied Mathematics 1976 National Meeting, Chicago, Illinois, June 16, 1976.

D. S. Kerr chaired a session on Computer Science Curriculum at the ACM SIGCSE Sixth Technical Symposium on Computer Science Education sponsored by the Association for Computing Machinery Special Interest Group on Computer Science Education, Williamsburg, Virginia, July 26-27, 1976.

D. S. Kerr was co-chairperson of a session on "Relational Data Base Systems" at the Association for Computing Machinery Annual Conference, Houston, Texas, October 20-22, 1976.

H. S. Koch presented a paper entitled "The Parallel Processing of Large Applications" at the Symposium on High Speed Computer and Algorithm Organization, University of Illinois, Urbana, Illinois, April 13-15, 1977.

K. B. Lakshmanan presented a paper entitled "Memory Complexity and Statistical Decisions" (Co-author: B. Chandrasekaran) at the Association for Computing Machinery Computer Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

M. J. Lee presented a paper entitled "Application of Markovian and Bayesian Techniques to the Analysis of Information" (Co-author: R. L. Ernst) at the Association for Computing Machinery Computer Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

E. W. Leggett, Jr. presented a paper entitled "Is the Travelling Salesman Problem Harder Than NP?" at the Association for Computing Machinery Computer Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

M. T. Liu presented a paper entitled "Message Communication Protocol and Operating System Design for the Distributed Loop Computer Network (DLCN)" (Co-author: C. C. Reames) at the Fourth Annual IEEE/ACM Symposium on Computer Architecture, Silver Spring, Maryland, March 23-25, 1977.

M. T. Liu reviewed proposals for the National Science Foundation during 1976-77.

L. Ma presented a paper entitled "The Design of the Distributed Loop Operating System" at the Association for Computing Machinery Computer Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

S. A. Mamrak was the keynote speaker at Career Day, sponsored by the College of Engineering, The Ohio State University, Columbus, Ohio, November 1976. Her speech was entitled "Computers".

S. A. Mamrak presented a paper entitled "A Network Resource Sharing Module to Augment User Cost-Benefit Analysis" at a conference on Trends and Applications 1976: Computer Networks, Gaithersburg, Maryland, November 17, 1976.

S. A. Mamrak was guest lecturer at Counselor's Day, sponsored by Western Electric and Bell Telephone Laboratories, Columbus, Ohio, February 1977. Her lecture was entitled "Career Guidance in Engineering".

S. A. Mamrak presented a paper entitled "Comparing Equivalent Network Services Through Dynamic Processing Time Predictions" at the National Computer Conference, Dallas, Texas, June 15, 1977.

S. A. Mamrak was a referee for Communications of the ACM, at the 1977 National Computer Conference, Dallas, Texas, June 15, 1977.

H. W. Mei presented an invited talk entitled "Recent Development in Unconstrained Optimization" at the National Bureau of Economics Research Computer Research Center, Cambridge, Massasschusetts, June 7, 1977.

K. C. O'Kane presented a paper entitled "A Single User MUMPS System for TSO" (Co-authors: E. A. Haluska, T. T. Augustyn) at the 1976 MUMPS Users' Group Conference, Madison, Wisconsin, October, 1976.

K. C. O'Kane presented a paper entitled "A Computer Simulation of Maintaining Total Lung Bypass for Basic Education (Co-author: J. B. Riley) at the Fifteenth International Conference of the American Society of Extra Coporeal Technology, Chicago, Illinois, February 1977.

K. C. O'Kane presented a paper entitled "A Computer Program Utilizing Numerical Taxonomy and Discriminant Analysis Techniques for Categorization of High Risk Pregnancies During the First Trimester" (Co-author: E. E. McColligan) at the 1977 Computer Science Conference, Atlanta, Georgia, February 1977.

A. E. Petrarca presented a paper entitled "Index Entropy as a Basis for Evaluating the Effectiveness of Vocabulary Control Algorithms Used in Automatic Indexing" (Co-author: W. S. Stalcup) at the Association for Computing Machinery Computer Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

A. E. Petrarca presented a paper entitled "A Bibliometric Analysis of Clothing Literature" (Co-authors: N. J. Fetterman, L. E. Dickey) at the American Home Economics Association's Sixty-eighth Annual Meeting, Boston, Massachusetts, June 27, 1977.

A. E. Petrarca was the ASIS representative to and the Educational Advisory Committee Chairman for the Columbus Technical Council. The function of the Educational Advisory Committee is to select the High School "Science Student of the Year" from among those students submitting science projects or reports in any area of science and technology, including computer and information science.

J. B. Randels, was elected Secretary at the Central Ohio Chapter of the Association for Computing Machinery, Columbus, Ohio, June 9, 1976.

L. L. Rose coached the Ohio State University's ACM Student Chapter team at the Association for Computing Machinery's East Central Regional Programming Contest, Bowling Green State University, January 7, 1977. The Ohio State University Team placed third among the ten universities who participated.

L. L. Rose presented a paper entitled "Information Flow and Analysis: Theory and Application" (Co-authors: J. Abilock, M. C. Yovits) at the Association for Computing Machinery Computer Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

J. Rothstein received the Best Paper Award for his paper entitled "On the Ultimate Limitations of Parallel Processing" presented at the 1976 International Conference on Parallel Processing, Detroit, Michigan, August 24-27, 1976.

J. D. Smith presented a paper entitled "A Methodology for the Performance Evaluation of DBMS Behavior Under System Usage" (Co-author T. G. Delutis) at the Association for Computing Machinery Computing Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

N. K. Sondheimer presented a paper entitled "A Natural Language Graphics Project" (Co-authors: D. Brown, H. W. Buttelmann, B. Chandrasekaran) at the Association for Computing Machinery Computing Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

J. Wang presented a paper entitled "Analysis and Simulation of the Mixed Voice/Data Transmission System for Computer Communication" (Co-author: M. T. Liu) at the National Telecommunications Conference, Dallas, Texas, November 29-December 1, 1976.

L. J. White presented a paper entitled "Development of a UDC Automatic Classification System" (Co-authors: A. E. Petrarca, L. Crawford, B. Brinkman, S. Mittal) at the Association for Computing Machinery Computer Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

P. M. K. Wong presented a paper entitled "A Methodology for Evaluating the Behavior of Query Driven Information Systems" (Co-author: T. G. DeLutis) at the Association for Computing Machinery Computer Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

M. C. Yovits has been elected East Central Regional Representative of the Association for Computing Machinery. His term of office runs through June 30, 1979.

M. C. Yovits chaired a session on "System Architecture and Organization" at the Association for Computing Machinery Computer Science Conference, Atlanta, Georgia, January 31-February 2, 1977.

M. C. Yovits participated in a symposium entitled "The Many Faces of Information Science," at the 143rd Annual Meeting of the American Association for the Advancement of Science, Denver, Colorado, February 20-25, 1977.

S.H. Zweben was Vice Chairman of the Central Ohio Chapter of the Association for Computing Machinery, Columbus, Ohio during 1976-77 and was elected its Chairman for 1977-78.

S.H. Zweben presented a paper entitled "Software Physics: An Approach to Analyzing Algorithms" at a meeting of the OSU Student Chapter of the Association for Computing Machinery, February 2, 1977.

S.H. Zweben is a reviewer for Harper & Row Publishers, Incorporated, New York, New York.

APPENDIX F

PUBLICATIONS OF THE DEPARTMENT OF

COMPUTER AND INFORMATION SCIENCE STAFF

BROWN, D. C.; BUTTELMANN, H. W. CHANDRASEKARAN, B.; KWASNY, S.C.; SONDHEIMER, N. K. Natural language graphics. In: Natural Language Interfaces, edited by D. Waltz, ACM SIGART Newsletter, No. 61, February 1977, pp. 57-58.

CHANDRASEKARAN, B.; PARENT, RICHARD. Molding computer clay -- steps toward a computer graphics sculptors' studio. In: Pattern Recognition and Artificial Intelligence. Academic Press, 1976, pp. 86-107.

DELUTIS, T. G. CODASYL -- The conference on data systems. Encyclopedia of Computer Science and Technology, Vol. 5, edited by Belzer et al, Marcel Dekker, Inc., 1976, pp. 72-87.

HSIAO, DAVID K.: HARSTON, R. A semantic model for data base protection languages. Systems for Very Large Data Bases, edited by E.J. Neuhold and P. Lockemann, North-Holland. 1976.

HSIAO, DAVID K. A software engineering experience in the management, design and implementation of a data secure system. In: Proceedings of the 2nd International Conference on Software Engineering, IEEE Catalog #76CH1125-4C, October 1976, pp. 532-538.

HSIAO, DAVID K.; HARSTON, H. REX. Full protection specifications in the semantic model for database protection languages. In: Proceedings of the Annual Conference of ACM, Houston, Texas, October 1976, pp. 90-95.

HSIAO, DAVID K.; HENNINGS, JAMES; HARSTON, R. A study of access control costs in database systems. In: Proceedings of 5th Texas Conference in Computing, Austin, Texas, October, 1976.

HSIAO, DAVID K.; BAUM, R. J. Database computers -- a step towards data utilities. IEEE Transactions on Computers. Vol. C-25, Issue 12, December 1976, pp. 1253-1259.

HSIAO, DAVID K.; KANNAN, KRISHNAMURTHI. The role of emerging technologies in building large database systems. In: Proceedings of IEEE Workshop on Picture Data Description and Management, April 1977, pp. 115-120.

KOCH, HARVEY S.: STAHL, F.; GUDES, E. The coordination of cryptographic and traditional access control techniques for protection in computer systems. In: Symposium Proceedings of Trends and Applications 1977: Computer Security and Integrity, IEEE Computer Society, May 1977.

COHEN, DAVID; LIU, MING T. Bridging the gap between principles and practices in microprogramming. ACM SIGMICRO Newsletter, Vol. 7, No. 2, June 1976, pp. 43-60.

LIU, MING T.; REAMES, C. C. Message communication protocol and operating system design for the distributed loop computer network (DLCN). In: Proceedings of the 4th Annual Symposium on Computer Architecture, March 1977, pp. 193-200.

[1] See Appendix G for Publications issued as part of the Department of Computer and Information Science Technical report series.

LIU, MING T.; MUFTIC, SEAN. Design of a secure computer system. In: Symposium Proceedings of Trends and Applications 1977: Computer Security and Integrity, IEEE Computer Society, May 1977, pp. 64-70.

MAMRAK, SANDRA A. Simulation of computer systems: A tutorial. In: Proceedings 7th Annual Pittsburgh Conference on Modeling and Simulation, Instrument Society of America, April 1976, pp. 38-42.

MAMRAK, SANDRA: MONTANELLI, R. G. Jr. The status of women and minorities in academic computer science. Communications of the ACM, Vol. 19, No. 10, October 1976, pp. 578-581.

MAMRAK, SANDRA A. A network resource sharing module to augment user cost-benefit analysis. In: 1976 Symposium on Computer Networks: Trends and Replications, IEEE Computer Society, November 1976, pp. 79-85.

MAMRAK, SANDRA A. Dynamic response time prediction for computer networks. Communications of the ACM, Vol. 20, No.7, July 1977, pp. 461-468.

MAMRAK, SANDRA A.; KIMBLETON, S. R. Comparing equivalent network services through dynamic processing time predictions. In: Proceedings AFIPS, 1977 NCC Conference, Vol. 46, pp. 455-460.

O'KANE, K. C.; HALUSKA, E. A. Perspectives in clinical computing. In: Advances in Computing, Academic Press, edited by Marshall C. Yovits and Morris Rubinoff, 1976.

O'KANE, K. C.; TRZEBIATOWSKI, G. L. Graduate level education in biomedical computing. Clinical Engineering News, Fall 1976.

O'KANE, K. C.; TRZEBIATOWSKI, G. L. Computers and health care: the role of university based education. ACM SIGBIO News, Vol. 2, 1977, pp. 4-7.

ROSE, LAWRENCE L.; HELLERMAN, H. Portable character processing in FORTRAN and fixed integer environments. In: IEEE Transactions on Software Engineering, Vol. SE-2, No. 3, September 1976, pp. 176-185.

ROSE, LAWRENCE L.; YOVITS, M. C.; ABILOCK, J. D. Development of a theory of information flow and analysis. In: AAAS Proceedings, Denver, Colorado, February 1977

ROTHSTEIN, JEROME. Quantum detection and estimation theory, by C. W. Hellstrom. Applied Optics, Vol. 16, April 1977, pp. 791-792.

YOVITS, MARSHALL C.; RUBINOFF, MORRIS, editors, Advances in computers, Vol. 15, Academic Press, 1976.

ZWEBEN, STUART H. A study of the physical structure of algorithms. In: IEEE Transactions on Software Engineering, Vol. SE-3, No. 3, May 1977, pp. 250-258.

PAPERS ACCEPTED FOR PUBLICATION

KRISHNASWAMY, R.; BUTTELMANN, H. W. Formal Methodology of translation. Information and Control.

KRISHNASWAMY, R.; BUTTELMANN, H. W. Formal methodology of translation. Information and Control.

PYSTER, A.; BUTTELMANN, H. W. Semantic-syntax-directed translation. Information and Control.

CHANDRASEKARAN, B. The thinking computer, mind inside matter, by B. Raphael. Creative Computing. (book review)

CHANDRASEKARAN, B.; JAIN, A. K. Independence measurement complexity and classification performance: an emendation. IEEE Transaction Systems: Man & Cybernetics.

CHANDRASEKARAN, B.; JAIN, A.K. On balancing decision functions. Proceedings IEEE International Theory Symposium, Ronneby, Sweden.

CHANDRASEKARAN, B.; LAKSHMANAN,K.B. Multiple hypothesis testing with finite memory. Invited paper, Cybernetics and Information Science.

CHANDRASEKARAN, B.; YOVITS, M.C. Artificial intelligence. (Originally appearing in Encyclopedia of Computer & Information Science.) Operations Research Support Methodology, Marcel Dekker.

LAKSHMANAN, K. B.; CHANDRASEKARAN, B. On finite memory solutions to the two-armed bandit problem. IEEE Transaction Information Theory.

CHANDRASEKARAN, B. Four papers selected for inclusion in Pattern Recognition, a collection of basic papers in computer and information science, IEEE Press, New York.

LIU, MING T.; PARDO, R.; BABIC, G. A performance study of distributed control loop networks. 1977 International Conference on Parallel Processing, August 1977.

LIU, MING T.; BABIC, G.; PARDO, R. Traffic analysis of the distributed loop computer network (DLCN) 1977 National Telecommunication Conference, December 1977.

LIU, MING. T.; OH, M. Interface design for distributed loop control networks. National Telecommunication Conference, December 1977.

MAMRAK, SANDRA A. The design and development of resource sharing services in computer communications: a survey. Advances in Computers, Vol. 16, Academic Press.

MAMRAK, SANDRA A.; RANDAL, J. M. An analysis of a software engineering failure. The Computer Journal.

MAMRAK, SANDRA A.; ABRAMS, M. D. Application constraints on the generation of test workloads. Computer.

MAMRAK, SANDRA A.; DERUYTER, P. Statistical methods for comparison of computer services. Computer

MEI, HOWELL HUNG-WEI; DENNIS, JOHN E. Two new algorithms for unconstrained optimization that uses function and gradient values. Journal of Optimization Theory and Applications (JOTA) 1977.

ROSE, LAWRENCE L.; HUGHES, C.E.; PFLEEGER, C. P. Advanced programming techniques: a second course in programming using fortran. John Wiley & Sons, Fall 1977.

SONDHEIMER, NORMAN K. Towards a uniform representation for spatial and temporal reference. Proceedings 5th International Joint Conference on Artificial Intelligence.

ZWEBEN, STUART H.; MCDONALD, M.A. An optimal method for deletion in one-sided height-balanced trees. Communications of the ACM

PAPERS SUBMITTED FOR PUBLICATION

LIU, MING T.; BABIC G.; PARDO, R. Performance study of distributed loop computer network (DLCN) 1977 Computer Networks Symposium, December 1977.

LIU, MING T.; PARDO, R.; BABIC, G. The distributed loop database system. 1977 Computer Networks Symposium, December 1977.

LIU, MING T.; MA, L. Control and communication in distributed processing. 1977 International Computer Symposium, December 1977.

LIU, MING T. The distributed loop computer network (DLCN) IEEE Transactions on Computers.

MAMRAK, SANDRA A.; AMER, P. D. A statistical classification approach to workload characterization. 1977 SIGMETRICS/CMG VIII Performance Conference.

MAMRAK, SANDRA A.; MONTONELLI, R.G. Computer science faculties: the current status of minorities and women. Communications of the ACM.

MEI, HOWELL H. W. A local convergence analysis of Davidon's 1975 optimally conditioned algorithm. Mathematical Programming.

MEI, HOWELL H. W. On the conditioning of DFP and BFGS updates for unconstrained optimizations. Journal of Computer and System Sciences.

MOORE, DANIEL J.; RUSSELL, B. Formal theories of data objects. ACM SIGACT-SIGPLAN Symposium on Principles of Programming Language.

LEGGETT, E. W.; MOORE, DANIEL. Classifying hard problems in the polynomial hierarchy. SIAM Journal of Computing.

SONDHEIMER, N. K. Semantic nets and spatial references. American Journal of Computational Linguistics.

SONDHEIMER, N. K. A semantic analysis of reference to spatial properties. Linguistics and Philosophy.

APPENDIX G

TECHNICAL REPORT SERIES

1968

YOVITS, M. C.; ERNST, R. L. Generalized information systems: Some consequences for information transfer. October, 1968. 47p. (OSU-CISRC-TR-68-1) (PB-180 929)

FILLMORE, C. J.; LEHISTE, I. Working papers in linguistics no. 2. November, 1968. 128p. (OSU-CISRC-TR-68-3) (PB-182 596)

FRIED, J. B.; LANDRY, B. C.; LISTON, JR., D. M.; PRICE B. P.; VAN BUSKIRK, R. C.; WASCHSBERGER, D. M. Index simulation feasibility and automatic document classification. October, 1968. 21p. (OSU-CISRC-TR-68-4) (PB-182 597)

ROTHSTEIN, J. Thermodynamics & information: Before, in and beyond quantum mechanics. December, 1968. 21p. (OSU-CISRC-TR-68-5) (PB-183 738)

FINLEY, JR., M. R. The development of a basic language for artificial intelligence. January, 1969. 24p. (OSU-CISRC-TR-68-6) (PB-182 305)

1969

COLOMBO, D. S.; RUSH, J. E. Use of word fragments in computer-based retrieval systems. February, 1969. 7+[9]p. (OSU-CISRC-TR-69-1) (PB-184 104)

WHITE, L. J. Minimum covers of fixed cardinality in weighted graphs. March, 1969. 14p. (OSU-CISRC-TR-69-2) (PB-183 737)

JACKSON, D. M. The construction of retrieval environments and pseudo-classifications based on external relevance. April, 1969. 74p. (OSU-CISRC-TR-69-3) (PB-184 462)

ELLIOT, D. E.; HUANG, S.; LANGENDOEN, D. T.; LEE, P. G.; LEHISTE, I. Working papers in linguistics no. 3. June, 1969. 181p. (OSU-CISRC-TR-69-4) (PB-185 855) (ED-060 689)

BRIGGS, G. E. Reaction time and uncertainty in human information processing. March, 1969. 36p. (OSU-CISRC-TR-69-5) (PB-184 135)

WHITE, L. J.; RUSH, J. E. Linear lists for spiro graphs. June, 1969. 69p. (OSU-CISRC-TR-69-6) (PB-194 402)

PETRARCA, A. E.; LAY, W. M. The double KWIC coordinate index. A new approach for preparation of high-quality printed indexes by automatic indexing techniques. April, 1969. 12 +[17]p. (OSU-CISRC-TR-69-7)*

*Journal of Chemical Documentation, 9, 256 (1969)

YOVITS, M. C. Information science: Toward the development of a true scientific discipline. June, 1969. 27p. (OSU-CISRC-TR-69-8) (PB-187 983)

PETRARCA, A. E.; LAY, W. M. The double KWIC coordinate index. II. Use of an automatically generated authority list to eliminate scattering caused by some singular and plural main index terms. August, 1969. 13p. (OSU-CISRC-TR-69-9)*

MCCULLOUGH, J. L. The acquisition of information across cultures: I. Persuasive role play, counterargument and attitude change. August, 1969. 18p. (OSU-CISRC-TR-69-10) (PB-197 508)

ERNST, R. L.; YOVITS, M. C. Information science as an aid to decision making. September, 1969. 22p. (OSU-CISRC-TR-69-13) (PB-189 666) (ED-054 782)

LANDRY, B. C. An indexing and re-indexing simulation model. June, 1969. 50p. (OSU-CISRC-TR-69-14) (PB-198 115)

SALVADOR, R. Automatic abstracting and indexing. June, 1969. 93p. (OSU-CISRC-TR-69-15)

STEVENS, D. W. A computer program for the reduction of flow tables. June, 1969. 97p. (OSU-CISRC-TR-69-16) (PB-189 679)

COLOMBO, D. S. Automatic retrieval systems and associated retrieval languages. 1969. 69p. (OSU-CISRC-TR-69-17) (PB-198 116)

SCHLESSINGER, J. D.; WHITE, L. J. Optimum prefix encoding. August, 1969. 85p. (OSU-CISRC-TR-69-18) (PB-198 117)

DAY, R.; WHITE, L. J. Hebbian neural simulation: Computer program documentation. (OSU-CISRC-TR-69-19) (PB-204 003)

REEKER, L. H. Extended finite state representation of infinite machines. September, 1969. 36p. (OSU-CISRC-TR-69-20) (PB-187 949)

WILLIAMS, N. T.; ERNST, R. L. A computer simulation of human short-term memory. 1969. 62p. (OSU-CISRC-TR-69-22) (PB-197 874)

BEZDEK, R. R. The acquisition of information across cultures: II. Social science research in a different culture. III. Cross-cohort activity and attitude change, by J. L. McCullough. January, 1970. 36p. (OSU-CISRC-TR-69-23) (PB-197 876)

1970

UNKLESBAY, M. K. A one step version of Younger's algorithm for bounded context grammars. 1970. 41p. (OSU-CISRC-TR-70-1) (PB-197 603)

*Proceedings of the American Society for Information Science, Vol. 6, 1969, 277-282.

LI, Y. Information structure and optimal policy. September, 1970. 18p. (OSU-CISRC-TR-70-2) (PB-197 605)

DILLON, S. R. Some procedures for finding substitution property partitions, substitution property covers, and cover pairs for finite state sequential machines. 1970. 79p. (OSU-CISRC-TR-70-3) (PB-197 643)

MATHIS, B. A.; WHITE, L. J.; JACKSON, D. M. Stability analysis of term similarities for information classification theory. July, 1970. 79p. (OSU-CISRC-TR-70-4) (PB-195 376)

MCGHEE, R. B.; DILLON, S. R. A paull-unger procedure for substitution property partitions. April, 1970. 16p. (OSU-CISRC-TR-70-5) (PB-192 120)

DAY, R. G.; WHITE, L. J. Study of a random search method for function minimization. March, 1970. 77p. (OSU-CISRC-TR-70-6) (PB-194 404)

PHARES, R.; WHITE, L. J. Identification of circuits in chemical structures. June, 1970. 73p. (OSU-CISRC-TR-70-7) (PB-194 396)

HARALSON, K. M.; WHITE, L. J. Optimal prefix codes for ensembles of N equiprobable messages using a binary alphabet. May, 1970. 105p. (OSU-CISRC-TR-70-8) (PB-197 642)

PETRARCA, A. E.; LAITINEN, S. V.; LAY, W. M. Use of the double KWIC coordinate indexing technique for chemical line notations. 1970. 14+[17]p. (OSU-CISRC-TR-70-9) (PB-198 269)

LAY, W. M.; PETRARCA, A. E. Modified double KWIC coordinate index. Refinements in main term and subordinate term selection. 1970. 11+[11]p. (OSU-CISRC-TR-70-10) (PB-197 567) (ED-054 815)

LYONS, J. J. The speed-accuracy trade-off in processing different classes of material. 1970. 38p. (OSU-CISRC-TR-70-11) (PB-198 114)

FILLMORE, C. J.; LEHISTE, I.; MELTZER, D.; TATHAM, M. A.; THOMPSON, S. A. Working papers in linguistics no. 6. September, 1970. 132p. (OSU-CISRC-TR-70-12) (PB-194 829)

ROTHSTEIN, J. Information generalization of entropy in physics. February, 1970. 22p. (OSU-CISRC-TR-70-24) (PB-192 128)

JACKSON, D. M. Basis for an improvability measure for retrieval performance February, 1970. 31p. (OSU-CISRC-TR-70-25) (PB-197 812)

DRACHMAN, B.; EDWARDS, M. L.; FILLMORE, C. J.; LEE, G.; LEE, P.; LEHISTE, I.; ZWICKY, A. M. Working papers in linguistics no. 4. May, 1970. 164p. (OSU-CISRC-TR-70-26) (PB-192 163)

1971

ROTHSTEIN, J. Patterns and algorithms. January, 1971. 8p. (OSU-CISRC-TR-71-1) (PB-197 604)

GROSU, A.; LEE, G. Working papers in linguistics no. 7. February, 1971. [243]p. (OSU-CISRC-TR-71-2) (PB-198 278) (ED-060 688)

CHANDRASEKARAN, B.; KANAL, L. On linguistic, statistical, and mixed models for pattern recognition. March, 1971. 33,A5p. (OSU-CISRC-TR-71-3) (PB-198 279)

WHITTEMORE, B. An example of the application of generalized information systems concepts to the quantification of information in a decision system: The examination of quantified information flow in an industrial control problem. May, 1971. 51p. (OSU-CISRC-TR-71-4) (PB-202 621)

OSTROM, T. M.; STEELE, C. M.; SMILANSKY, J. Information and attitudes: The effects of information context and perceived discrepancy on attitudes. May, 1971. 23p. (OSU-CISRC-TR-71-5) (PB-202 622)

LI, Y. Equipment replacement models: A generalization and extension. May, 1971. 17p. (OSU-CISRC-TR-71-6) (PB-200 548)

ELLIOTT, D.; GEIS, M.; GROSU, A.; NOBEL, B.; ZWICKY, ANN; ZWICKY, ARNOLD. Working papers in linguistics no. 8. June, 1971. 197p. (OSU-CISRC-TR-71-7) (PB-202 724)

BOND, Z. S.; GREGORSKI, R.; KEREK, A.; LEHISTE, I.; SHOCKEY, L.; WENDELL, M. V. Working papers in linguistics no. 9. July, 1971. 232p. (OSU-CISRC-TR-71-8) (PB-204 002) (ED-060 686)

JOHNSEN III, A. M. Performance in memory scan task under conditions of fixed versus varied memory sets. November, 1971. 49p. (OSU-CISRC-TR-71-9) (PB-210 432)

MEHAFFEY III, L. The spectral sensitivity of the turtle Pseudemys scripta elegans. November, 1971. 89p. (OSU-CISRC-TR-71-10) (PB-210 433)

WILLIAMS, J. D. Stimulus encoding and human information processing. November, 1971. 65p. (OSU-CISRC-TR-71-11)

SANDERS, S. A. A modification of a method of generating random numbers using a combination of two congruential generators. December, 1971. 76p. (OSU-CISRC-TR-71-12)

LANDRY, B. C. A theory of indexing: Indexing theory as a model for information storage and retrieval. December, 1971. 271p. (OSU-CISRC-TR-71-13) (PB-205 829) (ED-057 843)

OSTROM, T. M.; EDWARDS, J. D.; ROSENBLOOD, L. K. Integration of discrepant information in interpersonal attitudes. December, 1971. 43p. (OSU-CISRC-TR-71-14) (PB-210 500)

1972

WHITE, L. J.; GILLENSON, M. L. Optimum center location. January, 1972. 69,A6,B32p. (OSU-CISRC-TR-72-1)

MELTZER, D. Speech synthesis by haar functions with comparison to a terminal analog device. January, 1972. 135p. (OSU-CISRC-TR-72-2)

CHANDRASEKARAN, B.; JAIN, A. K. Quantization of independent measurements and recognition performance. March, 1972. 14p. (OSU-CISRC-TR-72-3) (AD-747 706)

CAMERON, J. S. Automatic document pseudoclassification and retrieval word frequency techniques. March, 1972. 165p. (OSU-CISRC-TR-72-4) (PB-210 435)

OSTROM, T. M.; SLOAN, L. R.; MC CULLOUGH, J. L. Information and attitudes: The effects of repetition and amount of information. April, 1972. 38p. (OSU-CISRC-TR-72-5) (PB-209 802) (ED-061 968)

LEHISTE, I.; MELTZER, D.; SHOCKEY, L.; GREGORSKI, R. Working papers in linguistics no. 12. June, 1972. 88p. (OSU-CISRC-TR-72-6) (PB-210 781) (ED-069 162)

EKONG, V. J. U. Rate of convergence of hermite interpolation based on the roots of certain Jocabi polynomials. June, 1972. 54p. (OSU-CISRC-TR-72-7) (PB-211 237)

WEIMAN, C. F. R.; ROTHSTEIN, J. Pattern recognition by retina-like devices. July, 1972. 154p. (OSU-CISRC-TR-72-8) (PB-214 665/2) (ED-065 144)

CHANDRASEKARAN, B.; REEKER, L. H. Artificial intelligence - a case for agnosticism. August, 1972. 28p. (OSU-CISRC-TR-72-9) (ED-069 296)

ROTHSTEIN, J. Loschmidts's and Zermelo's paradoxes do not exist. October, 1972. 9p. (OSU-CISRC-TR-72-10) (PB-213 712/8) (PB-214 666/0)

YOVITS, M. C.; CHANDRASEKARAN, B. Artificial intelligence. December, 1972. 39p. (OSU-CISRC-TR-72-11) (AD-760 782)

HSIAO, D. K.; DENICOFF, M.; BERGART, J. G. An annotated and cross-referenced bibliography on computer security and access control in computer systems. November, 1972. 57p. (OSU-CISRC-TR-72-12) (AD-755 225) (ED-078 879)

FOULK, C. R.; JUELICH, O. C. Smooth programs and languages. November, 1972. 16p. (OSU-CISRC-TR-72-13) (PB-218 805/0) (ED-071 683)

YOVITS, M. C.; WHITTEMORE, B. A generalized conceptual development for the analysis and flow of information. December, 1972. 31p. (OSU-CISRC-TR-72-14) (PB-215 530/7)

MATHIS, B. A. Techniques for the evaluation and improvement of computer-produced abstracts. December, 1972. 262p. (OSU-CISRC-TR-72-15) (PB-214 675/1) (ED-071 686)

1973

LAY, W. M. The double KWIC coordinate indexing technique: theory, design, and implementation. February, 1973. 250p. (OSU-CISRC-TR-73-1) (PB-228 181/4GI) (ED-072 826)

YOUNG, C. E. Development of language analysis procedures with application to automatic indexing. April, 1973. 298p. (OSU-CISRC-TR-73-2) (PB-227 088/2GI) (ED-078 843)

STRONG, S. J. An algorithm for generating structural surrogates of English text. April, 1973. 140p. (OSU-CISRC-TR-73-3) (PB-227 071/8GI) (ED-078 844)

HSIAO, D. K. Logical access control mechanisms in computer systems. July, 1973. 24p. (OSU-CISRC-TR-73-4) (AD-765 727/3) (ED-078 880)

WANG, P. T. R. Bandwidth minimization, reducibility decomposition, and triangularization of sparse matrices. September, 1973. 162p. (OSU-CISRC-TR-73-5) (PB-227 396/9GI)

BIERMANN, A. W.; BAUM, R.; KRISHNASWAMY, R.; PETRY, R. E. Automatic program synthesis reports. October, 1973. 62p. (OSU-CISRC-TR-73-6) (AD-771 332/4GI) (ED-086 167)

WYRICK, T.; HSIAO, D. K. System configuration study on the interconnection of the IBM 370/165, DEC System-10 and MICRO 1600/21 computer systems. October, 1973. 26p. (OSU-CISRC-TR-73-7) (AD-770 611/2GI)

1974

HSIAO, D. K.; KERR, D. S.; MC CAULEY III, E. J. A model for data secure systems (Part I). February, 1974. 39p. (OSU-CISRC-TR-73-8) (AD-778 657/7GI) (ED-090 983)

HSIAO, D. K.; KERR, D. S.; NEE, C. J. Context protection and consistent control in data base systems (Part I). February, 1974. 28p. (OSU-CISRC-TR-73-9) (AD-778 658/5GI) (ED-090 982)

BAUM, R. I.; HSIAO, D. K. A data secure computer architecture. July, 1974. 22p. (OSU-CISRC-TR-73-10) (AD-787 580/0GI)

RUSH, J. E.; PEPINSKY, H. B.; LANDRY, B. C.; MEARA, N. M.; STRONG, S. M.; VALLEY, J. A.; YOUNG, C. E. A computer assisted language analysis system February, 1974. 71p. (OSU-CISRC-TR-74-1) (ED-090 948)

REAMES, C. C.; LIU, M. T. Variable-length message transmission for distributed loop computer networks (Part I). June, 1974. 9p. (OSU-CISRC-TR-74-2) (PB-242 913/2GI) (ED-092 152)

KIRSCH, B. M. An improved error diagnositcs system for IBM System/360-70 assembler program dumps. June, 1974. 60p. (OSU-CISRC-TR-74-3) (PB-235 060/1GI) (ED-092 153)

COHEN, D.; LIU, M. T. Emulation of computer networks by microprogrammable microcomputers. June, 1974. 17p. (OSU-CISRC-TR-74-4) (PB-242 912/4GI)

BIERMANN, A. W.; KRISHNASWAMY, R. Constructing programs from example computations. August, 1974. 41p. (OSU-CISRC-TR-74-5)

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